UNI BASEL

Manual Preamplifier SP883d

Preliminary user manual/datasheet for the low power/low noise (LNP) charge preamplifier for APD&VPT/T readout in Panda EMC proto 192

Author: Werner Erni
Experimental Particle Physics Group of Prof. Dr. Bernd Krusche

in collaboration with Dr. Irakli Keshelashvili, Michael Steinacher, Universität Basel, CH; Universität Bochum, D; GSI Darmstadt, D; KVI Groningen, NL

Status: Preliminary Draft

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Revision History
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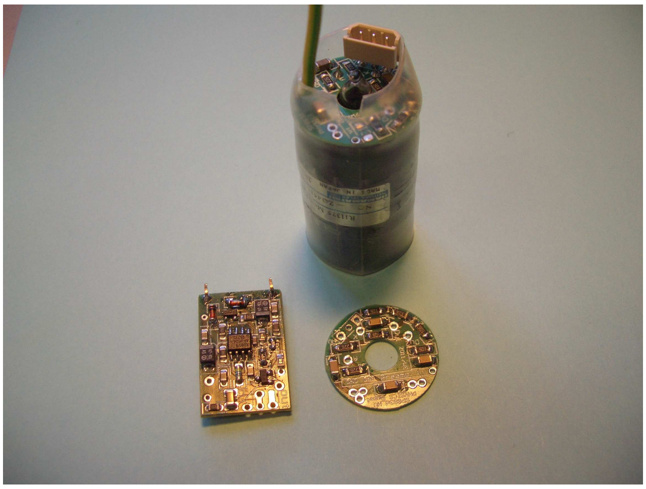


Photo: Preamp SP883d. Round HV-divider soldered to Hamamatsu VPT

Main Features of low noise/low power charge preamplifier model SP883d

- Low noise (high resolution) relative to power consumption
- For Vacuum Photo Triodes (VPT), Photo Tetrodes (VPTT) & APD
- Completely analog electronics
- Single ended, AC-coupled 50Ω positive signal output
- Integrated low power HV-Divider(Bleeder/Bias) for up to 1,5kV. Space saving, significant less cables (1 instead of 3)!
- Integrated low & high voltage power supply filter
- Reduced dimensions (length 28mm), short “stamp” format
- Two separate boards (PCB), without PCB-connectors
- Low cost with components of the shelf
- Operation at -25°C, radiation and magnetic fields
- Fast rise time (<20ns) for energy & time measurements
- Single range: reduces ADC-channels (cost), power, space
- Driver for signal transmissions integrated (drives 50 Ohm standard coaxial cables)
- Easy operation: Power supplies (LV+HV) in -> Signal out

Table of Contents (F9 to refresh)

Precautions

Electronic circuits can be damaged by Electrostatic Discharge, ESD. It is strongly recommended that all devices be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from performance degradation to complete device failure, sudden or while operated.
ESD is produced by walking on floors, through friction on isolating surfaces, shoes, clothes, etc.
Basic methods are not to touch, use conductive ESD-bags to store and grounding strips when handling the device.

Concept of the Panda Electromagnetic Calorimeter EMC readout

The Low Noise / Low Power Charge Preamplifier (LNP “Basel”-Preamp) is a discrete charge preamplifier which has an excellent noise performance in combination with low power consumption. It is designed for the readout of Photodetectors for the Panda Electromagnetic Calorimeter (EMC). The Photodetectors (LAAPD, VPT, VPTT) are attached to the end face of the lead tungstate scintillating crystals (PWO-II) which have a typical geometry of (200 x 20 x 20) mm^3. In comparison to a photomultiplier, theses photodetectors are working better in a strong magnetic field. Further, the vacuumphotodetectors as Vacuum-Photo-Triode (VPT) and the Vacuum-Photo-Tetrode (VPTT) are better for high radiation which occurs in the center of the forward endcap than the semiconductor device LAAPD. Therefore the barrel and the backward endcap of the EMC is equipped totally with LAAPDs and the forward endcap works with VPT/T’s and LAAPD’s dependent of the region. These devices act as photo detectors converting the scintillating light to an electrical charge. Then, the LNP-Preamp linearly converts the charge signal to a positive voltage pulse which is transmitted via a 50 Ohm line to the subsequent electronics.
Since the complete EMC including the preamplifiers will be cooled to -25℃ (to increase the light-yiel d of the PWO-II crystals), the power dissipation of the preamplifier has to be minimized. Low power dissipation leads to a smaller cooling unit and thinner cooling tubes; it also helps to achieve a uniform temperature distribution over the length of the crystals. The LNP-Preamp has a quiescent power consumption of 45 mW. The power dissipation is dependent on the event rate and the photon energy; at very high rates combined with the maximum photon energy, the power consumption is increased up to 90 mW.

Introduction

This LNP Preamplifier was built for applications where low noise and low power consumption is essential, as specially for the PbWO-crystal read-out of Panda Calorimeter at GSI, Darmstadt. Preamps with lower noise are available on the market but then with higher power consumption.

The model SP883d is the latest version of a family of preamps originally designed for APD with a capacitiy of up to 500pF (f.e. two paralleled Hamamatsu S8664-1010 or S11048).
The output is a positive low noise single ended 50Ω-signal, useable for energy and timing measurement. Therefore, no shaping is made on board, this must be done externally. The shaping time for energy measurement defines then the noise. While the signal/noise ratio with VPT is comparable to those with APD, the absolute signal and noise level is much lower and therefore the sensitivity is higher and all activity to prevent from noise must be even better.
The influence of the noise from the preamplifier is proportionally higher in relativity to the vacuum photodetector with lower capacitance.

The realized mechanical shape was chosen, to fit into the foreseen limited space for the Proto 192 (crystals) for the Panda FW endcap also with the longer glass-tubes from Hamamatsu. A round PCB shape was not possible for this space.
The Preamp is foreseen to work at -25℃, but can also be operated at higher temperatures, but with more noise (around +20% @ 20℃).
Vacuum Photo Tubes are not highly temperature sensitive in comparison to the APD's and isolate the Preamp termally from the crystal. With APD's an additional temperature barrier or distance is necessary.

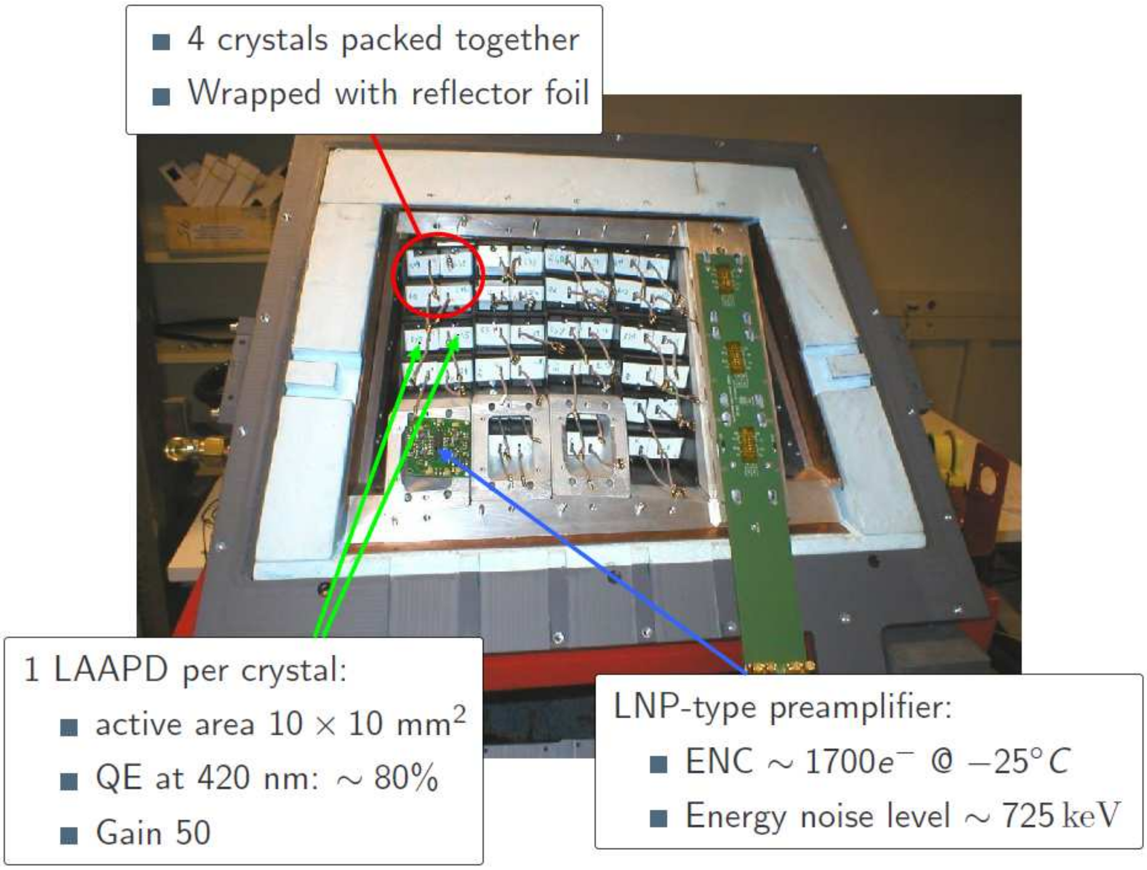
The originally concept was built for a range of around 10MeV to 10GeV, but lower energies may be detected with a good measured setup.

A low power HV-divider circuit for up to 1.5kV is also implemented. This low power circuit is a new method, because manufacturers of tubes recommends higher power consuming bleeder circuits. Hence it was possible to implement the divider on the preamp itself in the cooled - and therefore power loss critical sector- of the detector. This innovative concept reduces not only problematic temperature gradients to the photodetector and the crystals, but also the amount of HV-cables and therefore space and cooling losses.
To implement the additional HV-circuit on the reduced area, the preamp was split into two PCB's. In addition, it prevents from leakage currents to the input of the amplifier stage. Each type of photodetector needs his very own typical divider-circuit which is placed on one of the two boards. As tradeoff this results in slightly more noise.
A precise power-on-point HV-generation onboard ("active base") is not foreseen due to additional heat generation and the magnetic fields at that point. The use of unshielded magnetic components as inductors for power conversion and filtering is problematic.

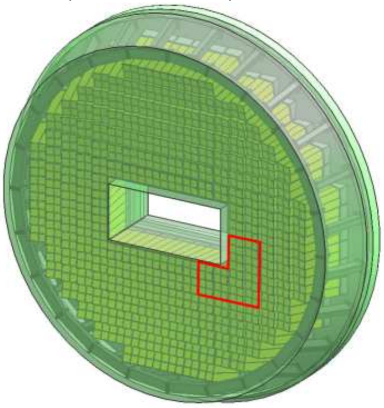
The leave out of connectors reduces material, volume, costs and weight and increases reliability. The preamp is connected to the next signal chain stage (either a shaper or a distribution panel) via short wires/cables/PCB and the connection to the photodetectors is also possible with short distance.
The preamplifier is made of commercial standard low cost components of the shelf.

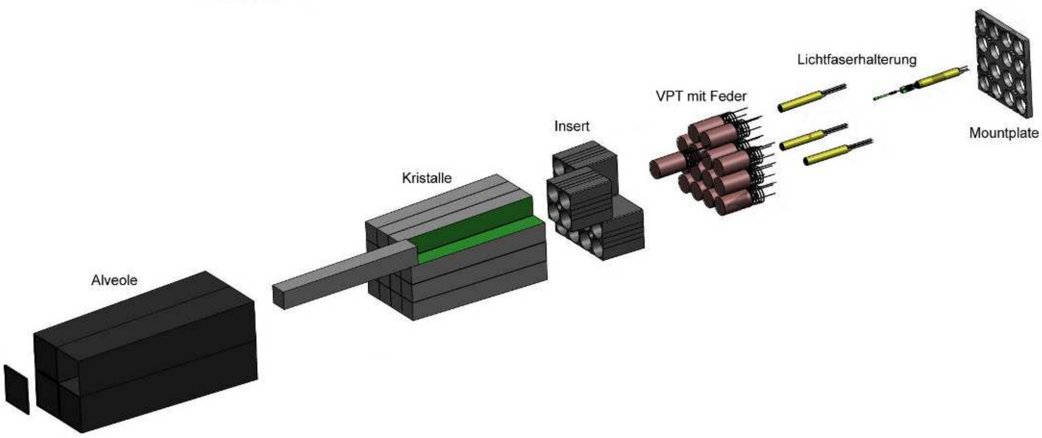
An adapted version for use with APD's is also available. The appropriate HV-circuit (filter) which works also as an interconnection to the APD's is designed for two preamps/crystal of either type SP883d (18x28mm) or SP883a02 (18x48mm).
This version has reduced series filter resistance to reduce the voltage drop at high rates.

Panda EMC Barrel Proto60 (Picture Tobias Eissner)
Uni Basel, IPN Orsay, Uni Giessen, etc.



Panda EMC Forward Endcap Proto 192 (192 crystals, red marked part)
Uni Basel, Uni Bochum, etc.





http://panda-wiki.gsi.de/cgi-bin/view/EMC/ForwardEndcapEMC

Main tasks/challenges

- Low noise at low power
- Signal transmission/output voltage/dynamic range
- Low overall cost/easy operation
- Energy and time measurement (no onboard-shaper)
- Max. Rate/pile-up
- Integration of a low power loss HV bleeder for operation in cooled areas
- Mechanical integration in limited space with onboard-HV
- Flexible design for different photodetectors APD/VPT/VPTT

Family of LNP preamplifiers

Since the APD-Version of the preamplifier was developped years ago and many measurements and tests were performed with it, refer to the datasheet SP883a02 or the TDR 2008 for specific data for use with APD's. The actual version SP883d and the new types of vacuumphotodetectors were developed in 2010. Therefore they are still in test phase. Below an overview is shown:

Model/Type No.	Photodetector	max. HV	Description
SP883a	APD 10x10mm	500V	APD single channel family, 18x48mm, PCB: 0.8mm
SP883a01	VPT short glass	1000V	With round shaped filter PCB, soldered to tube
SP883a02	APD 10x10mm	500V	compensation for up to 500pF
SP883a02_1000V	APD rectangular	1000V	With 1000V capacitors (Bias APD: ca. 650V) compensation for up to 500pF
SP883a03	APD rectangular	1000V	Low Gain, Low Bias HV filter resistor (150k), 100pF* compensat.
SP883b	APD 10x10mm	500V	quad channel (Proto60), 46x46mm
SP883c	VPT metal Hamamatsu	1000V	without onboard HV divider, PCB: 4-Layer 1.6mm
SP883(c)d		1500V	Prototyp: Umbau von SP883c auf Funktion v. “d“
SP883d		1500V	Combi family (APD/VPT/VPTT), “stamp-format”, 2 PCB à 18x28mm, with onboard HV-Divider
SP883d_VPT(Ham)	VPT glass, Hamamatsu	1500V	with onboard HV-Divider for VPT (750V)
SP883d_VPTT(Ham)	Tetrode glass, Hamamatsu	1500V	with onboard HV-Divider for VPTT (750V)
SP883d_VPTT(RIE)	RIE	1500V	with onboard HV-Divider for RIE VPTT's (1200V)
SP883d_APD	APD rectangular	450V	3MΩ-filter for 2 APD-Bias, w. 100pF* compensat.
SP883e	VPT/T	1000V	Smaller, higher rate

100pF*-Compensation value is implemented (designed for VPT/T). This may cause to a little slower rise time, but better stability, specially at lower temperature. Also used for LowGain-APD (SP883a03). Standard value for APD with +/-6V is 47pF, for +8V/-2V 100pF.

Note: type number key, Example SP883d01_APD:

SP	<u>S</u>chematic <u>P</u>lan
883	Projectnumber Electronics Lab Physics Basel for the Panda EMC Preamp
d	Model/Type
01	Revision/Version 1
_APD	variante/adaption

For use with Photodetectors, f.e. for following devices:

Model	**Type**	**Notes**
Hamamatsu LA APD S8664-1010	APD, ca. 450V	270pF, square 13.7x14.5mm(10x10)
Hamamatsu LA APD S11048	APD, ca. 450V	270pF, rectangular 9x18mm(6.8x14)
Hamamatsu LA APD Low capacity (not radiation hard)	APD, ca. 630V	…pF, rect. 9x18mm (6.8x14)
Hamamatsu Photo-Triode R2148, short glass (Proto)	VPT, 750V	
Hamamatsu Photo-Triode R2148MOD, short metal	VPT, 750V	(shielded "Kovar" FeNiCo can), ∅24x 30mm
Hamamatsu Photo-Triode R11375 MOD3	VPT, 750V	∅24x 40+10mm
Hamamatsu Photo-Tetrode R11375 MOD	VPTT, 750V	∅24x 40+10mm
Research Institute Electron (RIE, St. Petersburg) Photo-Tetrode	VPTT, 1200V	∅22x 32+…mm
RIE FEU-189 (21mm), IHEP/MELZ	VPT	
RIE FEU-190 (25mm), IHEP/MELZ	VPT "CMS"	
Other: Photonis, ET, …	Prototype	

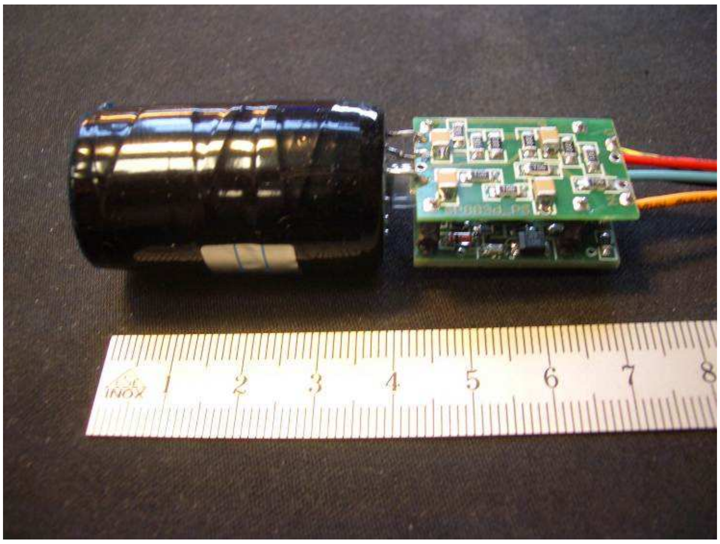
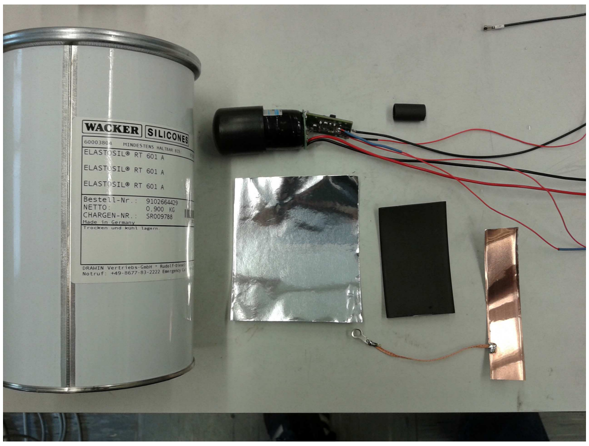


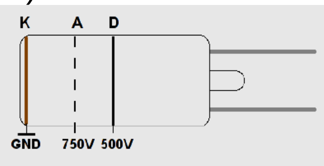
Photo: SP883d

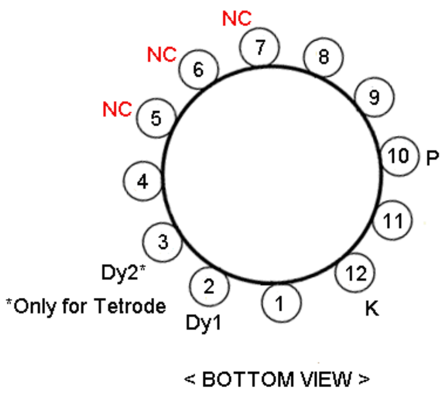
Glue candidates (silicones):
Dow Corning RTV 3145
Elastosil RT 601



Photodetectors

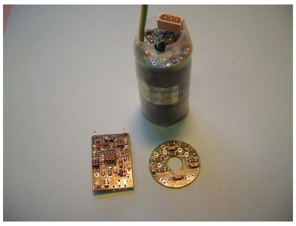
a.) Hamamatsu Triode R11375MOD3



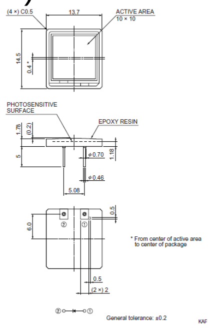


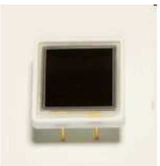
Hamamatsu Pin numbers (new version)

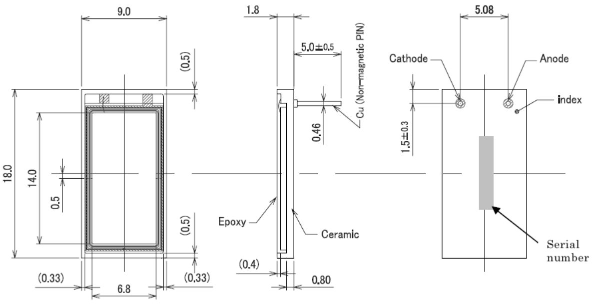
b.) Hamamatsu Tetrode R11375MOD



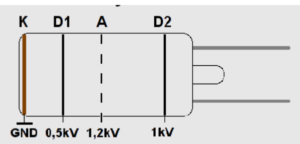
c.) Hamamatsu LAAPD S8664-1010 (“old”); S11048 (“new rectangular”)

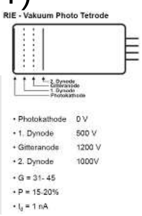






d.) RIE Tetrode (VPTT)

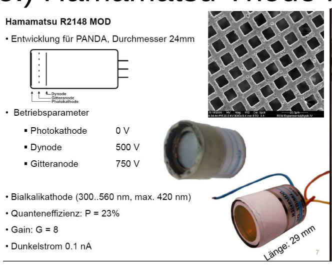


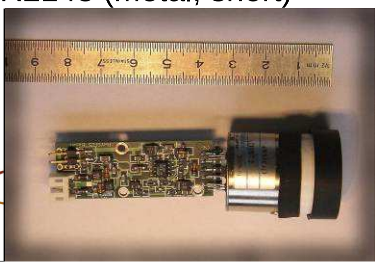


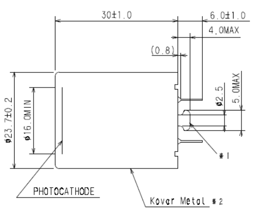
Thanks to Michael Leyhe, RUB, 29.1.2010
VPTT (RIE) with silicone Isolation and protection

VPTT (RIE) without silicone potting

e.) Hamamatsu Triode R2148 (metal, short)







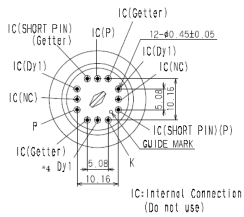


Photo: R2148MOD connected to LNP Version SP883c

Short Data for type SP883d

Max. Bias Voltage	+1500VDC (+450V for APD)
Power Supply, floating	max. +/-6V, +6mA/-1.5mA
Power Supply for increased output voltage range (limits rate!)	+8V/-2V (max.+10V/-2V)
Quiescent power consumption	45mW
Power consumption (depending on rate and energy)	90mW with 50Ω load
Max. single pulse input charge	4pC
Max. 500 kHz burst event rate input charge	0.3pC
Max. continous 500kHz event rate input charge	8pC
Output Signal, Sensitivity	ca. +0.5V/pC@50Ω
Output Signal, Sensitivity	ca. +1V/pC ohne Last
Max. output voltage (with +6/-6V power supply)	>+2.5V@50Ω
Max. output voltage (with +6/-6V power supply)	>+5V@1kΩ
Max. output voltage (with +8/-2V power supply)	>+3.5V@50Ω
Output impedance	50Ω
Rise Time (with input load/detector capacitance 22pF)	ca. 15…<20ns
Feedback time constant	25µs
Input Load/detector capacitance	0…300pF
(SP883a02	80…500pF)

Typical noise performance	
with RIE-Tetrode/1100V (Ti=250ns, Td=2µs)	ca.625e-RMS(1mVRMS)@+25℃
with Cd=270pF (Ti=250ns, Td=2µs)	ca.2500e-RMS@+25℃
*Typical noise performance @ Cd=22pF (shaping 650ns)	ENC=235 e^-_{RMS} @ –25 ºC
*Typical noise performance @ Cd=22pF (shaping 200ns)	ENC=450/300e-RMS @-25℃
*Noise floor (shaping 200ns)	3MeV RMS
*Practical energy range/Dynamic Range (@VPT: 16aC/MeV)	6MeV…10GeV(250GeV)/1650

Typical noise performance with APD-Preamp SP883a02	ca.2100e-RMS@+25℃
APD Hamamatsu S8664-1010 (Ti=250ns, Td=2µs)	ENC = 1’700 e^-_{RMS} @ –25 ºC
Cd = 270 pF (Ti=250ns, Td=2µs)	ENC = 1’250 e^-_{RMS} @ –25 ºC
Cd = 82 pF (Ti=250ns, Td=2µs)	ENC = 510 e^-_{RMS} @ –25 ºC

Shaping (Integration 250 ns /Diff. 2 µs: Measured Noise RMS	@270 pF: 2600e (@82pF: 900e)
Shaping 250 ns /250 ns Measured Noise RMS	@270 pF: 2870e (@82pF: 1360e)

Operating Temperature	-25℃ …70℃
Humidity	non condensating
Dimension without wires	18 x 28 x ca. 10mm
Weight	>4g

*measured on a modified single board prototype, by Michael Steinacher, 2008, Uni Basel. see datasheet SP883a01.

Depends on different conditions, has to be verified in every application.

Note: Oscilloscope measured value of 1 mV rms is around 625 electrons rms [electrons rms = µV/1,6].

General remarks for operation

- This Preamplifier was designed to work directly with the VPT or VPTT from RIE or Hamamatsu, but can also be adopted for other detectors and mechanical designs.
- As a photon energy of 100 MeV corresponds to a pulse peak of only 3.2 mV the subsequent electronics has also to be designed with low noise performance.
- To save space, cables are soldered directly onto the PCB.
- The use of an AC coupled device has many advantages, as to prevent common mode GND-level problems and crosstalk, but might also cause problems, because the shift of the signal baseline on the trigger branch side at high and fast changing rates. To prevent this, the signal output is terminated with 50Ω. The transmission line (PCB/shielded flat or coaxial cable) and the input of the following shaping amplifier must have also 50Ω impedance.
- The output signal is about 0.5V/pC when terminated with 50Ω (1V/pC unterminated).
- The peak output is an optimised voltage for ADC-Inputs (2V).
- The Preamp has one single ended output and is therefore optimized for ADC‘s with 2.5V Inputs (f.e. Wiener, Struck, CAEN, etc.).
- The signal must be measured relative to its proper ground, as it is widely used in critical signal processing. Baseline restoring with shaper. Ref.: E. Kowalski “Nuclear Electronics”, Springer-Verlag, p.106ff, 163
- Prevent the preamp from electrostatic discharge (ESD), specially if the input is open (no VPT).
- Do not touch the boards because of creepage currents through salts from hands..
- Floating power supply +/-6V, f.e. from a NIM-Chassis, the Basel model SP903b or a laboratory power supply (alternatively +/-5V).
- Floating HV low noise power supply (often a linear regulated HV power supply as the Fluke 341A).
- The filter-circuit of the preamplifier is designed for positive HV, Max. voltage is +1500VDC
- The voltage divider is placed on the preamplifier with only one HV-wire to save space and thermal conductivity.
- The power consumption of the voltage divider is significantly lower than the original circuits recommended from manufacturers, to make an on-board divider possible for cooled experiments.
- The power consumption of the voltage divider is in competition with fewer cables/copper.
- A good 6-side shielding around the preamp must be provided to insure low noise operation. Connect the case shield to the preamp via mounting holes, cable shields, Supply-GND.
- To proceed low noise measurements all coaxial cables and connectors must be in perfect condition. Prefere BNC before Lemo for low level analog signals. Warm-up the instruments.
- The short rise time allows precise timing measurements (timing resolution down to under 2ns possible, depending on read-out
- NP0 Ceramic Capacitors are used in the critical signal path, X5R/X7R with appropriate temperature behaviour are used for decoupling and power supply filtering.
- Test pulse coupling via a 1 pF Capacitor
- For use in high magnetic fields (tested up to 1.2T, but more expected)
- The rectangular APD with smaller capacitance and higher bias-voltage (typ.+630V) is also possible, but they are less radiation hard.
- Radiation Hardness is not yet fully tested. Implementation of suitable technology: CMOS+JFET
- The "long tail" of the LNP-Preamp output results from the feedback-network (1 pF//25Meg). The resulting 25 us is a compromise between low-noise performance and high-rate capability (pile-up). In principle this time-constant can be reduced, but you will get more noise. The shaper after the preamplifier can reduce this fall-time without any problems as long as the preamp doesn't go to saturation due to pile-up.
- The "undershoot" of the signal results from the AC-coupling of the output. Proper adopting of the signsal by the shaper can solve this.

Power–up procedure

Low Voltage power supply (+/-6V) should switched on first, before the HV and therefore with signal.
Normal operation is given with a supply current of around 6mA on +6V and 1mA on -6V. A higher supply current indicates ringing or defect.
Power up the HV via a ramp. If not, the ISEG HV-supply will switch off, because of relatively high current from loading the capacitors.

Application Hints for best operation

To get lowest possible noise it is essential to take extremely care to the overall-construction.
Example: A real measured noise level is: with good ground-connection 2.9mV (Ground via case and Power Supply), with a poor GND (only via coax-shield) 4.3mV. That's a difference of roughly +50%!
So:
The best way of using the LNP charge-preamp (SP883x) in an experimental setup is as following:
- Connect the photodetector (APD, VPT/T) with a short (lmax = 100 mm) coax-cable to the LNP preamp; or even better connect directly to the LNP preamp.
- Leave the photodetector electrically floating; this means that the APD-ground comes from the LNP preamp via the outer shield of the short coax-cable.
- Place the photodetector/coax-cable/LNP preamp in a electrically floating metallic (e.g. Alu) box which is grounded by the output of the LNP preamp (e.g. by a BNC wall-feed-trough).
- For the photodetector HV-bias voltage use a low noise **floating** supply; use a shielded SHV or MHV cable to connect the bias-voltage to the metallic box via SHV/MHV feed-through (this interconnects the ground of the bias-supply and the output of the LNP preamp).
- Use a low noise (linear regulated) and **floating** power supply for the LV-supply of the LNP preamp (+/-6 V or +8 V/-2 V).
- The reference ground of the metallic-box is coming via the 50 Ohm BNC cable connecting the LNP preamp output to the oscilloscope/DAQ. The oscilloscope/DAQ **has to be connected to earth/ground**.

In general it is very important that **only one ground** (oscilloscope/DAQ) is connected to the metallic-box, otherwise nasty ground-loops will interfere with the very sensitive signals.

Noise (Datasheet SP883a01)

To reach the required low detection threshold of only several MeV, the noise performance of the preamplifier is crucial. The VPTs have an outside diameter of 25 mm and a typical photocathode with a diameter of 18.5 mm, resulting in an active area of circa 268 mm^2. Compared to the active area of the LAAPD (100 mm^2) this is an increase of a factor 2.7. The VPT anode capacitance is around 22 pF which is more than ten times lower than the capacitance of the LAAPD; this results in a much lower noise from the LNP-Preamp. Thus, the shielded cable between the VPT and the LNP-Preamp has a significant impact on the total detector capacitance; it must be kept as short as possible.
The dark current of the VPT is significant lower than the one from the LAAPD; 1 nA compared to 50 nA, both measured at a room temperature. On the other hand the quantum efficiency (QE) of the VPT is only about 20%, compared to 70% of the LAAPD. Further the internal gain (M) of the VPT is only around ten, which is five times lower than the LAAPD.
The noise floor of the LNP-Preamp at –25℃ loaded w ith an input capacitance of 22 pF, has a typical equal noise charge (ENC) of 235 e^-_{RMS}. This is measured with an ORTEC 450 shaping filter/amplifier with a peaking-time of 650 ns. Because the VPT has almost no dark current the noise is not increased due to the leakage current of that photo detector.
Assuming 100 photons/MeV at the end face of the cooled (–25℃) PWO-II crystal would result in 43 photons/MeV on the active area of the VPT. This is coming from the fill factor of 40%: VPT active area of 268 mm^2 with respect to an end face area of about 625 mm^2. Since the end face not covered by the VPT will be masked by highly reflective material, we assume 50 photons/MeV on the VPT. By applying the QE and the internal gain of the VPT, a primary photon with the energy of 1 MeV induces an input charge of 16 aC (100 e^-) to the preamplifier. So an ENC of 235 e^-_{RMS} corresponds to an energy noise level of about 2.4 MeV_{RMS}. This is almost the same energy noise level as achieved under the same conditions in the barrel with the LAAPD readout (2 MeV_{RMS}). At the same photon energy, the signal from LNP-Preamp connected to a VPT is a factor of nine smaller, but also the noise is a factor of more than seven smaller compared with the LAAPD. That's why the signal to noise is in the same order when using a VPT or an LAAPD for the readout of a PWO-II crystal.
All these numbers above are related to the VPT type RIE-FEU-190 used in the CMS ECAL. By using new VPT, the energy noise level will be reduced remarkable. This may also be necessary, because the noise level is increased as the shaping time is decreased. Shorter shaping times are mandatory to cope with the expected high event rates in the endcap. By decreasing the peaking-time from 650 ns (reference values) to 200 ns the noise level is raised by around 25%. So the noise floor with the more realistic shaping with a peaking-time of 200 ns corresponds to 3 MeV_{RMS}.

Troubleshooting Guide

Source/Effect	Typical source	action
General		
Noise pick-up	wires to detector	Connect as close as possible to tube, f.e. VPTT (RIE) with socket/without silicone
Noise conducted	Switchmode Power Supply, motors, vacuum pumps, cooling, etc.	Low noise floating power supply, well filtered, shielded cables (connect to GND on LNP side)
Noise radiated	Switchmode Power Supply, VME-crates, Digital electronics, PC	Distance, shielding
Noise exceeded		Increase shaping time (tradeoff: pile-up)
Hum, noise	Ground loop	Only floating power supplies, starpoint ground
Ca. 1 kHz rolling	? Scope measurements	Use (Struck) VME-ADC
Cut-off HV	HV current limit	Ramp-up HV
HV changes	ISEG HV CAN Bus	Ignore result while traffic on CAN Bus
noise	ISEG HV CAN Bus	Ignore result while traffic on CAN Bus
Crosstalk/induction	Monitors, oscilloscopes, PC's	Distance, short shielded cables
Shadow pulses	Reflections from signal transmission	Mismatched 50 ohm termination
Phantom pulses	Dielectric absorption/leaks in capacitors?/stray current on PCB?	
Uncorrelated signals	Microphony of tube/ceramic capacitor Moving cables	Avoid vibration
	Schrotrauschen/Shot noise	
"Firework" of pulses	multiple separate HV Power supplies	use 1HV with HV-Divider ("Bleeder" circuit)
"Spratzen"		Improve HV-Isolation, cleaning PCB/cables
Afterpulses (duration 20 …100ns)	Luminous reactions of electrodes due to electron bombardment	Blanking if systematic/time correlated
Afterpulses (0.1…10us)	Ionization of residual gas traces	Blanking if systematic/time correlated
	Light leak from ambient	Cover light tight
Noise typ. 100kHz	noise of oscilloscope input amplifier, display +shaper	Calculate difference
Noise factor 2	Mismatched Impedance	Use correct termination (50ohm)
rms noise value		use histogram mode scope for rms
Rate dependency	High resistance HV-Divider	Lower resistance HV-Divider
noise		Warm-up
Unlinearity		Add capacitor to divider
Microphony	Ceramic capacitors changes volume during voltage changes	Coupling via PCB
EMC		
Magnetic field	Stray fields (trafo, motor, pump)	Shield
Magnetic field	magnets	Shielded tube (f.e. Hamamatsu R2148)
Electric field	FL-ballast, Switchmode PS	6-side shield
Electrostatic damage	Triboelectricity, touching	Conductive packaging, don't touch
Ambient		
Microphony	Sound, vibration, shock	Silence, mech. decoupling
Humidity/moisture	Cold-warm cycles/bedewing	drying
Temperature		Cooling for noise reduction
Creep currents	Dust/grease/salt (from hands)	don't touch preamp & photodetector
Spontaneous avalanche		
Spurious pulses	Myon	With crystals
Defects photocathode	Light	Do not operate & wait after exposure
Arcing	HV	Isolate preamp
	contamination	

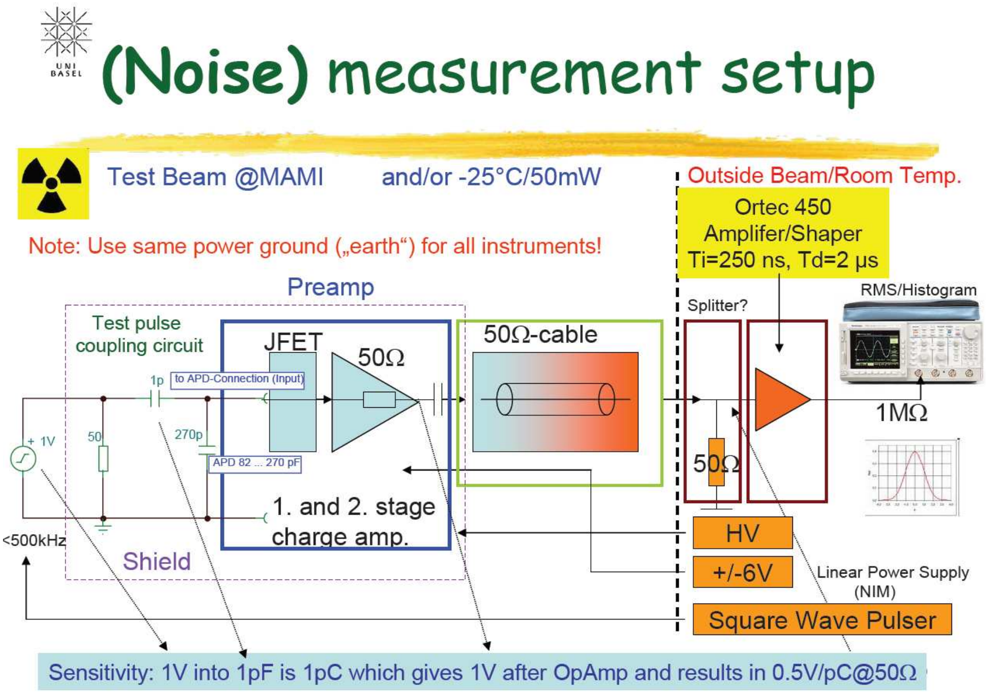
Comparing noise measurement results

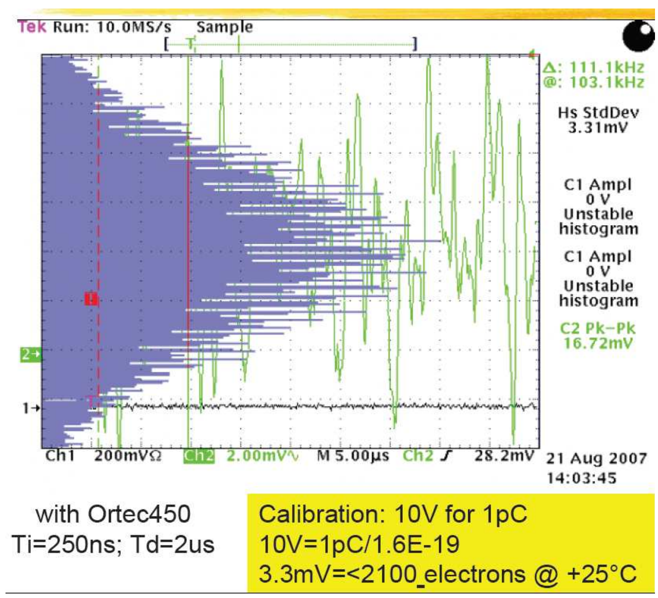
To get comparable noise measurement results, take care of following points :

- Measure V rms (if Vpp on oscilloscope divide by 9), standard deviation
- Photodetector : Capacity and gain
- Crystal : Light yield, wrapping, glue
- Subtract noise floor of equipment (measure test setup without preamp)
- Calibrate signal chain with 1V signal pulse (or LED-Pulser or Gain of photodetector)
- Multiply with gain of shaper
- Temperature : Decide cooled at -25℃ or at room te mperature
- Grounding of preamp (if only via signal coax) multiply with a factor of around 1,5
- Shielding: 5/6-side metal, neighbourhood (FL-lamp, PC, VME, cooler, pump, etc.)

Noise measurement setup

Noise R.M.S.=SQRT [(measured value)^2-(noise floor)^2]
Noise p-p viewed on the oscilloscope is approximately 9 times higher than the real rms-value.

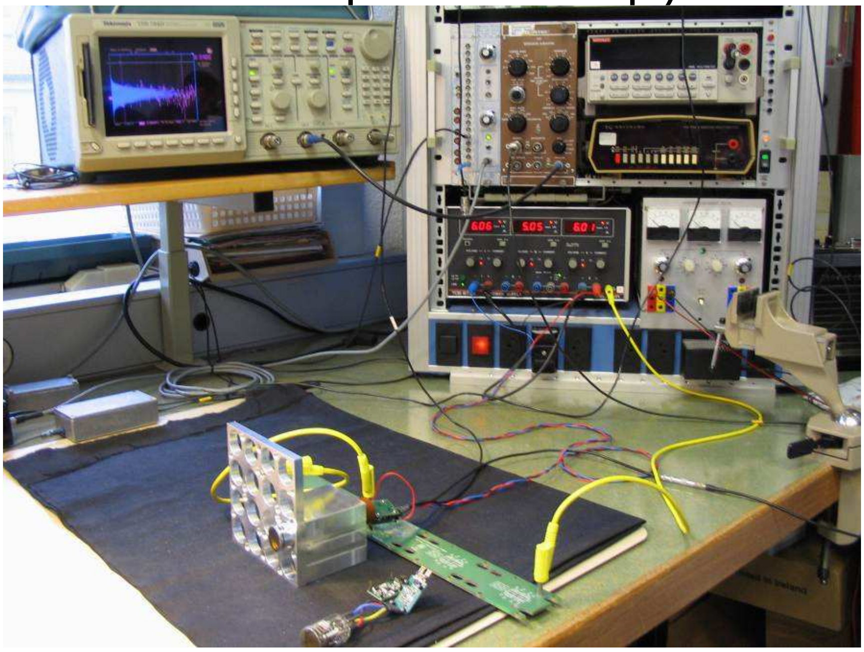




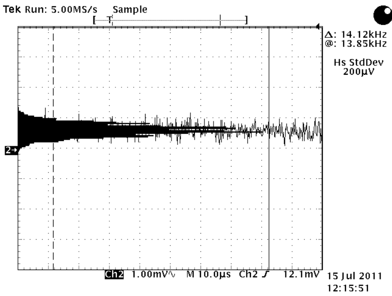
Q[pC]xU[mVrms]/10/1.6E-19=Noise [electrons]
z.B. Noise in mV Std.Dev. x 1000/1.6= electrons

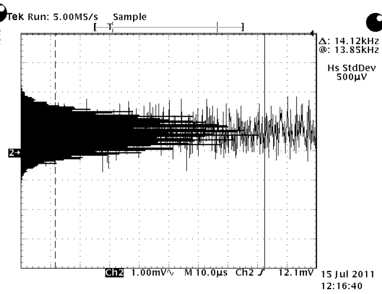
Measurements taken with approx. peaking time of 650ns (Ti=250ns, Td=2µs)
Similar test results are taken with peak sensing ADC (see test setup SP903c below)

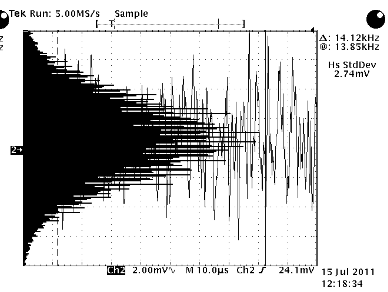
Example (Noise measured with shaper and oscilloscope)



Source of the noise

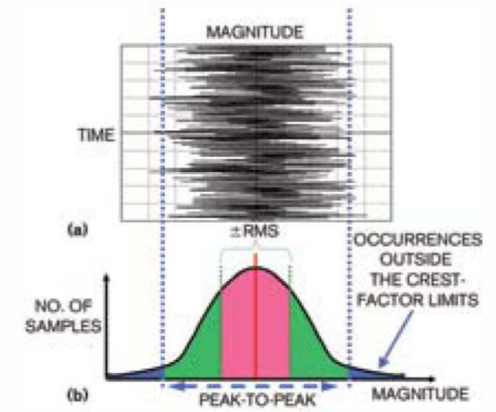




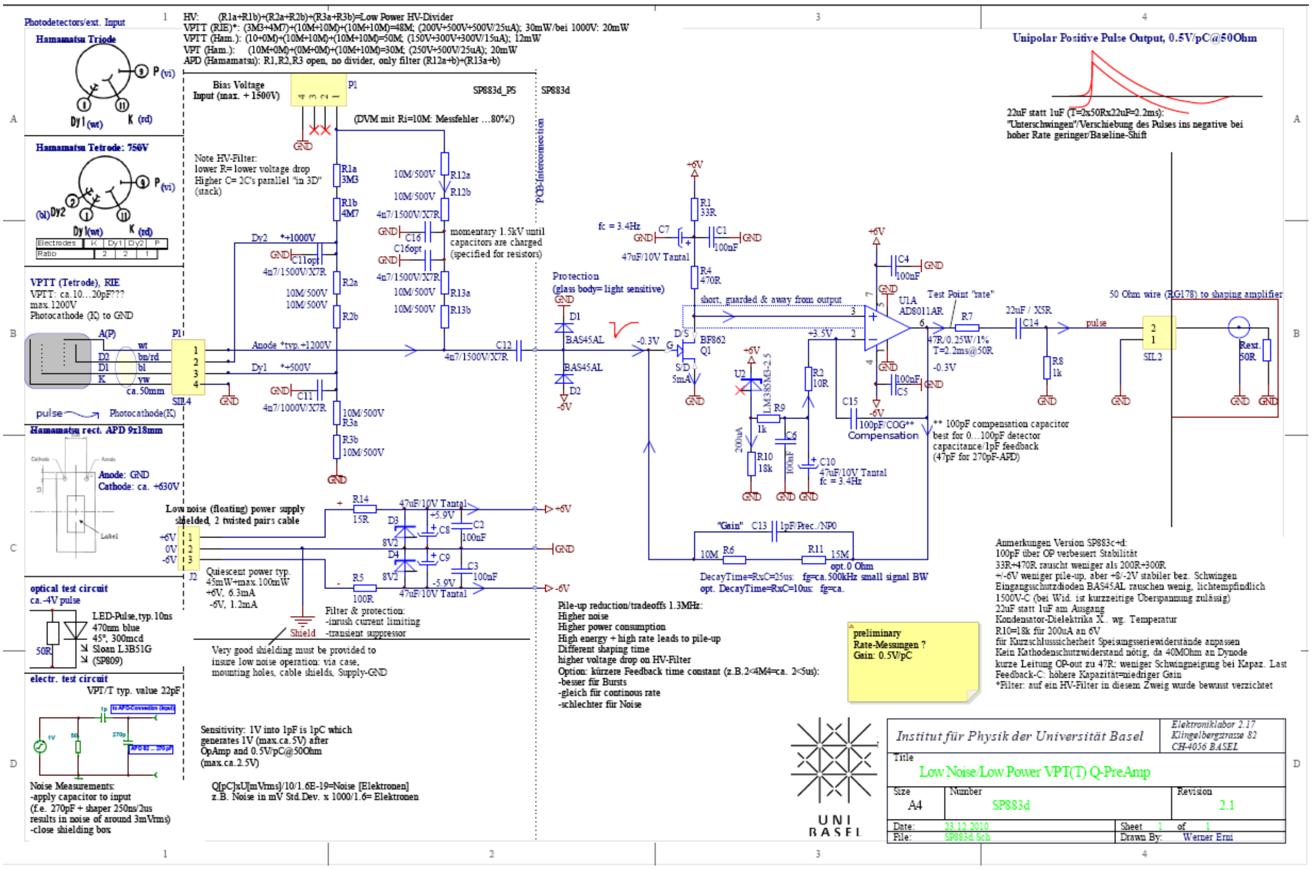


Left: oscilloscope input: 0.2mV rms
Middle: measurement setup: 0.5mV rms
Right: with amplifier +270pF: 2.7mV rms

Method:



Schematic diagram SP883d (for VPT/VPTT)

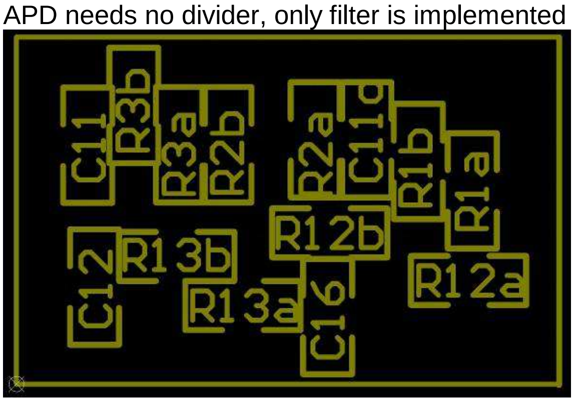


Differences between the versions of SP883d_PS rectangular (VPT, VPTT, …)

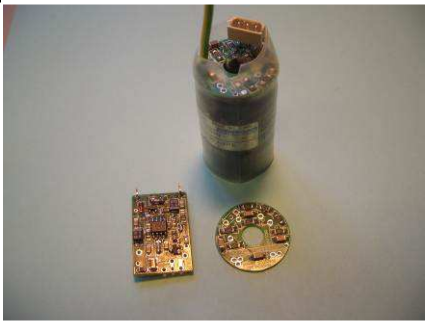
	R1a	R1b	R2a	R2b	R3a	R3b	max U/ I	Power consumption
VPTT (RIE)	3M3	4M7	10M	10M	10M	10M	1200V/25uA	30mW (20mW with 1000V)
VPTT (Ham.)	10M	0	10M	10M	10M	10M	750V/15uA	12mW
VPT (Ham.)	10M	0	0	0	10M	10M	750V/25uA	20mW
APD*	Open	Open	Open	Open	Open	Open		

Note: all resistors 10M are 500V rated

APD needs no divider, only filter is implemented

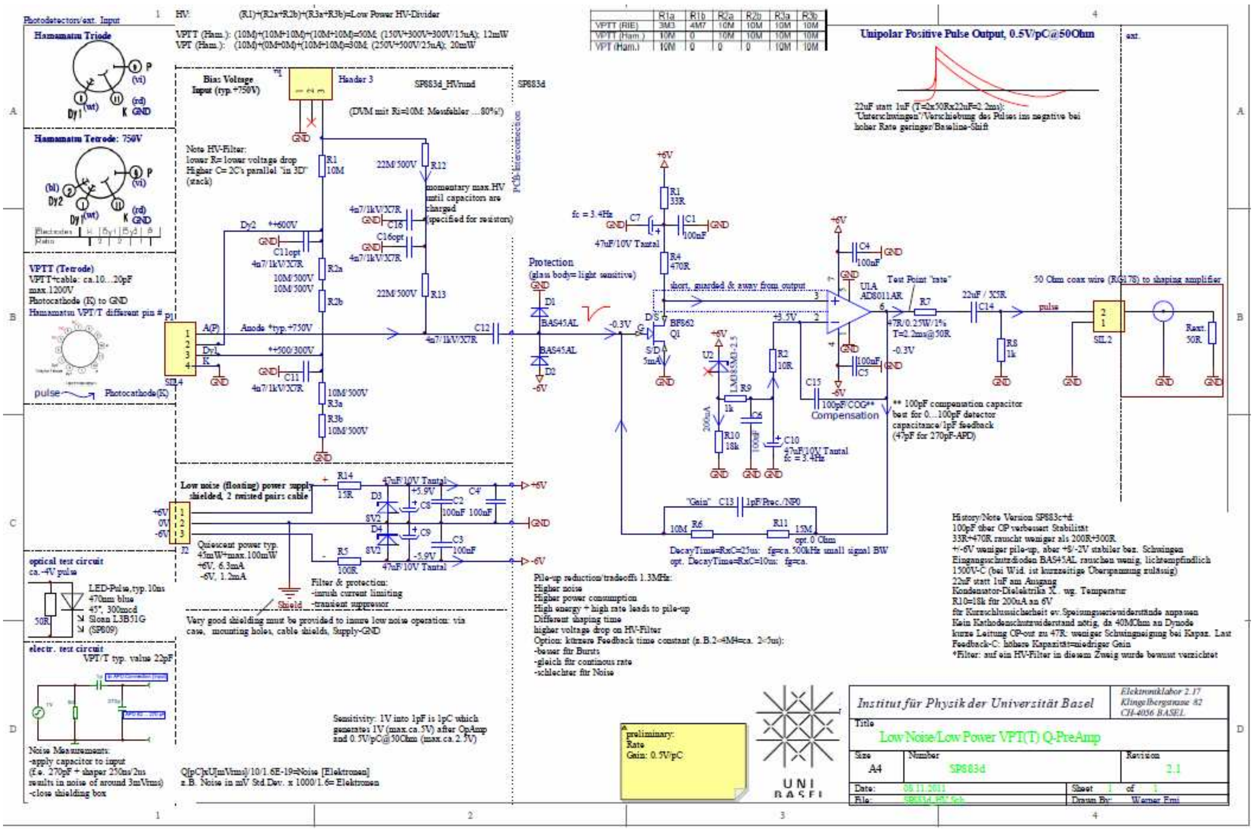


Round Divider PCB, SP993d_HV for Hamamatsu VPT/T



	R1a	R1b	R2a	R2b	R3a	R3b	max U/ I	Power consumption
VPTT (Ham.)	10M	-	10M	10M	10M	10M	750V/15uA	12mW
VPT (Ham.)	10M	-	0	0	10M	10M	750V/25uA	20mW

Note: all resistors 10M are 500V rated
APD needs no divider, only filter is implemented
R12 + R13 is each a single 22M/500V resistor instead of 2x10M in series to save space
R1b is not implemented on the PCB to save space



Circuit/component function description

The circuits of initial versions are described in detail in the Panda TDR from June 2008, chapter 6.4.2.

HV Divider (Bleeder)	significantly lower current/power (15...25µA) than in standard applications (around 0.5…1mA). Example for commercial low current type: Ortec 276L (200µA). Disadvantage is a higher sensitivity to EMC.
MiniMelf resistor	Inrush current limit (tantal protection), filter
Zener Diodes	Input protection device, transient overvoltage, polarity
Low leakage diodes	FET input protection
Ceramic Caps	X5R, X7R, C0G, NP0 for low temperature operating range
Tantal Caps	

Additional notes:

Gain: lower gain = higher feedback capacity (+ change value of compensation capacitor)
Dynamic range, higher positive power supply voltage (while lowering the negative), f.e. +8V/-2V
Compensation: 100pF best for 0…100pF detector capacitance, min. 47pF for APD (270pF). A higher cap value slows down the pulse rise time. 100pF is also better when operated with +8V/-2V.
A high Feedback resistor lowers the Johnson noise.

Circuit description for VPT-preamp SP883a01

The AC-coupled input stage consists of a low noise J-FET of the NXP type BF862. It is specified with a typical input voltage noise density of 0.8 nV/sqrt(Hz) at 100 kHz and at room temperature. The J-FET input capacitance is 10 pF and the forward transductance is typically 30 mS at a drain-source current (I_{DS}) of 5 mA. Along with the 470 Ohm AC-dominant drain resistor this transductance results in a typical AC-voltage gain of 14 for the J-FET input stage. The gate of the J-FET is protected against over voltages by two low leakage silicon diodes of the type BAS45AL.

The input stage is followed by a broadband (300 MHz), fast (2'000 V/µs) and low power (±1 mA) current feedback operational amplifier of the type AD8011AR from the company Analog Devices. With its typical input voltage noise density of only 2 nV/sqrt(Hz) at 10 kHz, this amplifier suits well for such a low noise design.

The proper frequency compensation is performed by the capacitor C13 (100 pF), in combination with R2 (10 Ohm); this leads to high frequency feedback to the inverting input of the operational amplifier. Overshoot and ringing can be efficiently suppressed and this compensation also prevents from oscillations when no VPT is connected.

The output of the operational amplifier is DC-coupled via the feedback network (1 pF // 25 Meg Ohm) to gate of the J-FET. In parallel the output is AC-coupled via a 1 µF capacitor and a 47 Ohm series resistor to the output of the LNP-Preamp. Therefore the output voltage is divided by a factor of two if it is terminated with 50 Ohm.

With a symmetrical supply voltage of ±6 V the output voltage can swing symmetrically between the positive and negative supply when high continuous event rates at high energies occurs. The LNP-Preamp draws a typical quiescent current of 6.3 mA from the +6 V supply and 1.2 mA from the –6 V supply; this leads to a total power consumption of only 45 mW.

To set the 5 mA operating point of drain-source current through the J-FET, a gate voltage in a range of –0.2 V to –0.6 V (typically –0.3V, depending on the DC characteristics of the individual J-FET) has to be applied. This negative DC voltage is fed from the output of the operational amplifier via the 25 Meg Ohm resistor to the gate of the J-FET. The operating point (I_{DS}=5 mA) is fixed by the well filtered DC voltage applied to the inverting input of the operational amplifier. This set point voltage is obtained by subtracting 2.5 V from the positive supply voltage (+6 V) by using a 2.5 V reference diode. So the same voltage drop of 2.5V must also be present over the total drain resistor of 503 Ohm (470 Ohm + 33 Ohm); this results in a stabilized DC drain current of 5 mA.

The gate input of the J-FET is decoupled by a 4.7 nF high voltage capacitor.

As the voltage drop over the LP filter for the VPT bias voltage has to be proven. At high rates in combination with high energies, a maximum current of 80 nA is flowing trough the VPT; mainly drawn from the dynode bias voltage supply. The planned series resistance of the LP filter is 40 Meg Ohm, resulting in a maximum voltage drop of 3.2 V. By using the typical gain sensitivity of 0.1% per volt of the VPT, this voltage drop corresponds to a maximum energy/rate error of –0.32%, which is acceptable. By reducing the series resistance of the LP filter, this energy/rate error could be further minimized.

Circuit description APD-preamp SP883a02

The circuit diagram of the LNP-Preamp is shown in *Figure 3*. It is the same circuit for the single channel- and the Quad LNP-Preamp, except that for the quad version the voltage reference (U2) and its supply (R10, C6) is common for all the four channels.

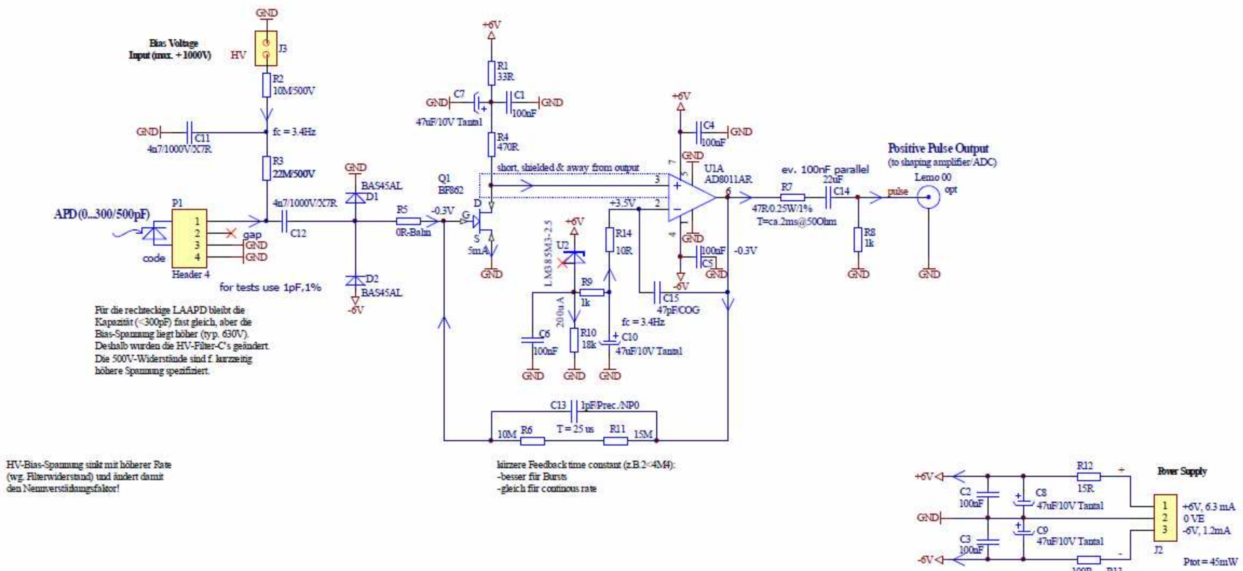
The AC-coupled input stage consists of a low noise J-FET of the type BF862 from the company NXP Semiconductors (former Philips). This industrial standard J-FET is often used in preamplifiers of car radio receivers. It is specified with a typical input voltage noise density of 0.8 nV/sqrt(Hz) at 100 kHz and at room temperature. The J-FET input capacitance is 10 pF and the forward transductance is typically 30 mS at a drain-source current (I_{DS}) of 5 mA. Along with the 470 Ohm AC-dominant drain resistor this transductance results in a typical AC-voltage gain of 14 for the J-FET input stage. The gate of the J-FET is protected against over voltages by two low leakage silicon diodes of the type BAS45AL.

The input stage is followed by a broadband (300 MHz), fast (2'000 V/µs) and low power (±1 mA) current feedback operational amplifier of the type AD8011AR from the company Analog Devices. With its typical input voltage noise density of only 2 nV/sqrt(Hz) at 10 kHz, this amplifier suits well for such a low noise design.

The proper frequency compensation is performed by the capacitor C13 (47 pF), in combination with R14 (10 Ohm); this leads to high frequency feedback to the inverting input of the operational amplifier. Overshoot and ringing can be efficiently suppressed and this compensation also prevents from oscillations when no APD is connected or unshielded wires are used between the LNP-Preamp and the APD.

The output of the operational amplifier is DC-coupled via the feedback network (1 pF // 25 Meg Ohm) to gate of the J-FET. In parallel the output is AC-coupled via a 1 µF capacitor and a 47 Ohm series resistor to the output of the LNP-Preamp. Therefore the output voltage is divided by a factor of two if it is terminated with 50 Ohm.

Note to the text: 47pF is C15 not C13 (as shown in diagram)

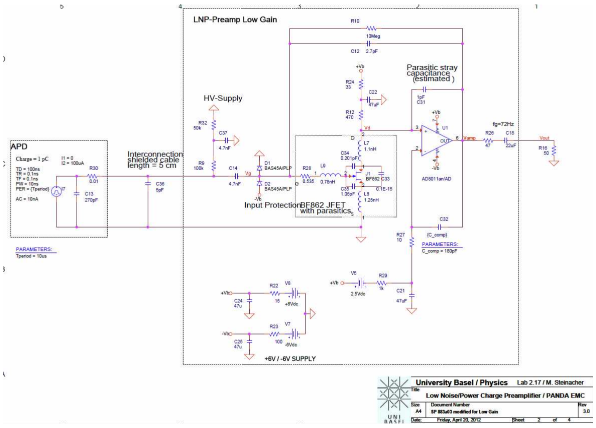


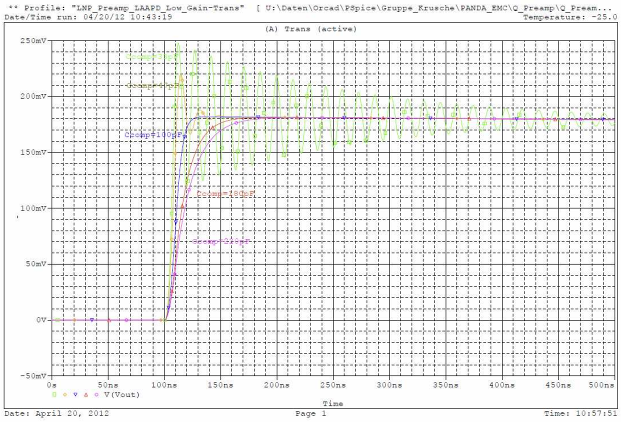
With a symmetrical supply voltage of ±6 V the output voltage can swing symmetrically between the positive and negative supply when high continuous event rates at high energies occurs (see *Figure 4*). The LNP-Preamp draws a typical quiescent current of 6.3 mA from the +6 V supply and 1.2 mA from the –6 V supply; this leads to a total power consumption of only 45 mW. Operating with an asymmetric supply voltage of +8V and -2V gives more restrictions at high continuous event rates, but is principally possible; it results in a little higher power consumption of 50 mW.

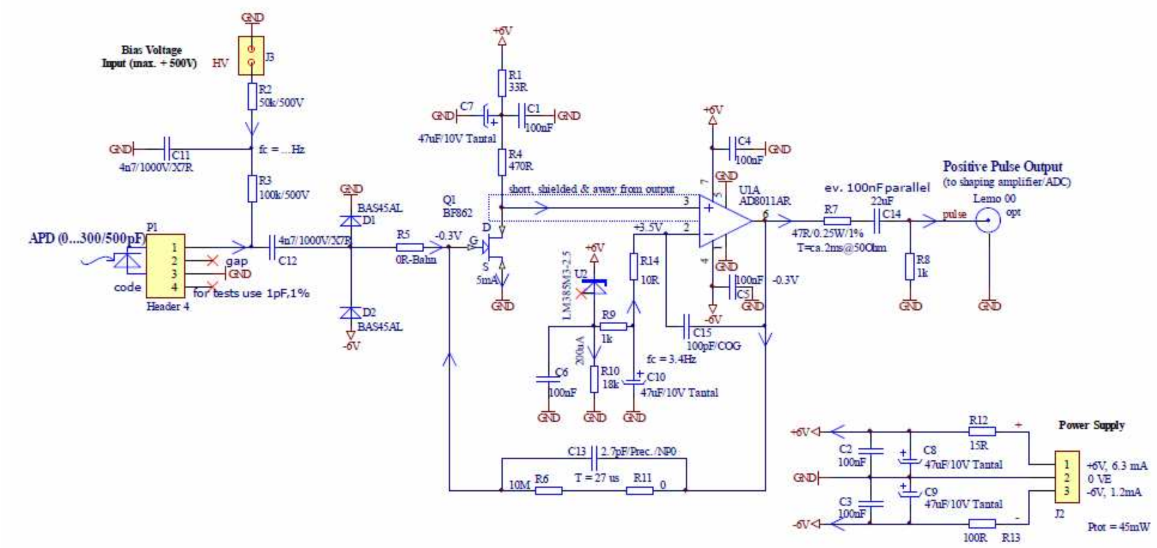
To set the 5 mA operating point of drain-source current through the J-FET, a gate voltage in a range of –0.2 V to –0.6 V (typically –0.3V, depending on the DC characteristics of the individual J-FET) has to be applied. This negative DC voltage is fed from the output of the operational amplifier via the 25 Meg Ohm resistor to the gate of the J-FET. The operating point (I_{DS}=5 mA) is fixed by the well filtered DC voltage applied to the inverting input of the operational amplifier. This set point voltage is obtained by subtracting 2.5 V from the positive supply voltage (+6 V) by using a 2.5 V reference diode. So the same voltage drop of 2.5V must also be present over the total drain resistor of 503 Ohm (470 Ohm + 33 Ohm); this results in a stabilized DC drain current of 5 mA.

SP883a03 (APD-Pramp "LowGain") PSpice Simulation

The Lower Gain, with 2,7pF and 10MΩ Feedback, needs a different compensation. Instead of 47pF in SP883a02, 100pF is used to prevent oscillations.







Version SP883a02:
R5=0R für 270pF/10R für 82pF APD
33+470R rauscht weniger als 200+300R
+/-6V weniger pile-up als mit +8/-2V
47pF-Kompensation über OP bringt Stabilität
Low noise Eingangsschutzdioden BAS45A
C14 neu 22uF/X5R (1206) statt 1uF (besseres High Rate Verhalten),
teilweise wurde 22uF/Y5U verwendet (schlechte Temperaturstabilität)

Version SP883a03 (lower gain/HV-Filter):
C13: 2,7pF statt 1 pF (gain)
R11: 0 statt 15M (time constant)
C15: 100pF statt 47pF (Compensation)
C11, C12: 1000V statt 500V
R2: 50k statt 10M
R3: 100k statt 22M

Für ältere rechteckige LAAPD bleibt die Kapazität (<300pF) fast gleich, aber die Bias-Spannung liegt höher (typ. 630V).
Deshalb wurden die HV-Filter-C's auf 1kV geändert. Die R's vertragen kurzzeitig höhere Spannung.
Für die neueren LAAPD liegt die Bias-Spannung wieder <500V.

Wiring & Assembling

Differences between SP883d Prototypes and Serie –Version.

On Prototypes the LV-Filter and Pads for wires were on the thin PCB. For series this LV-circuit was moved to the thicker Amplifier-PCB (to enable the possibility to use it autonomously for APD's). This increases also convenience for assembling.

Wiring for series-version:

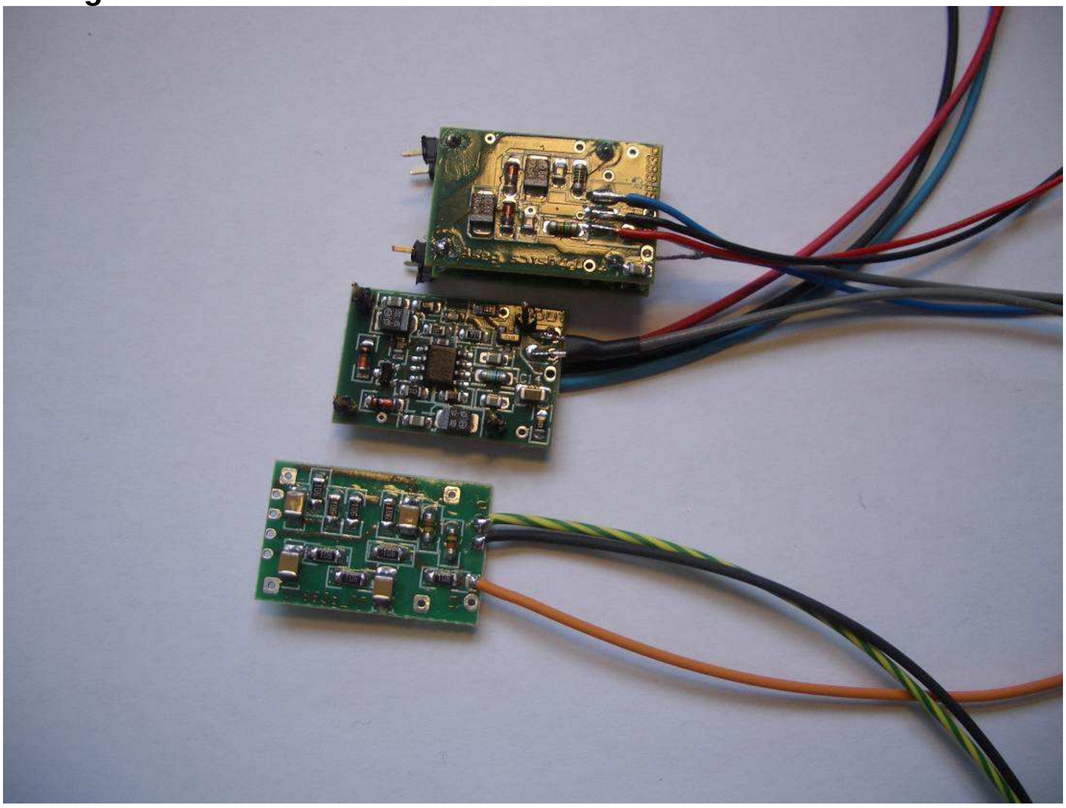
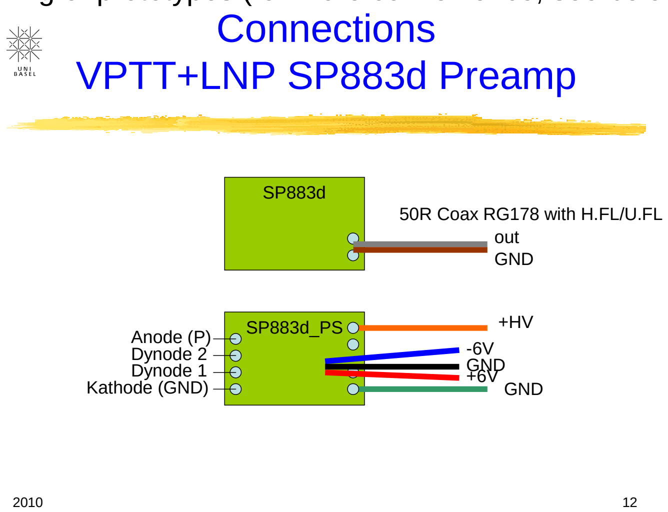


Photo shows from top to down:

1. LV (red:+6V/black:GND/blue:-6V)
2. Signal (50 Ω coax), direct to the PCB or via a ITT-crimp part
3. HV (orange) and GND (black and optional yellow/green)

Wiring of prototypes (for more convenience, see below):



Note:
The GND of the Preamps is connected via the green/yellow litz-wire to the Power-Distribution-PCB.

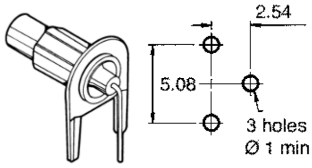
The shield (f.e. Aluminium-tube, d=25mm?) is also connected through the spring.

1. Connecting/wiring of power supply

Because the Hamamatsu Triode/Tetrode R11375 MODx is significantly longer than previous versions (f.e. R2148), there is no space for connectors on the PCB. Therel
ore, wires are soldered directly to the PCB. For assembling, the connectors will be mounted to the free end of the wires to connect to the power supply distribution board (and shaper).
Use a floating output power supply (f.e. laboratory power supply Toellner 8735), SP903b from Basel, in some cases via a NIM-Crate Adapter or similar.

The signal output should be wired with a 50 Ω coaxial cable (f.e. RG178). The 2nd edition of the PCB (series) includes the additional possibility to solder a RG178 (∅1.8mm) coax-cable via ITT Cannon 055-939-9039-AR6, available at Avnet Express or Newark, Part Number: 95F6346. For RG174 (∅2.8mm) via 055-939-9049FCD (Farnell: 121-5645).





Another solution for connecting the coax shield is to solder the shortened shield of the partly dismanteled cable to the testpoints (keystone test points/compona.ch 220 202) and the inner conductor direct to the PCB:


2. Isolation

There is high voltage on the board and the VPT/T. Isolate for up to 1.5 kV. Isolation can provided by shrinking tube or plastic tube.

3. VPT/T connection

a.) Because the original semi flexible wires from Hamamatsu for the R11375 are not delivered with a socket and therefore not constructed for space-critical use. Because of the advice from the manufacturer, not to cut the pins and not to solder near the glass body, we preferred flexible litz-wires, but nevertheless it is not the optimum to save space in depth.

Anyhow, due to the fact that the manufacturer cuts and solders the pins of the tubes close to the glass body (as they are delivered in fact), there is obviously a possibility to connect them in a much better way, but it has to be proceeded very carefully:
Solder the pins for A(P) and K of the tube directly to the solder points of the preamp and bend the Dynode pin under no force at the glass (take the pressure off the glass with pliers) in a way, that a short wire can be soldered to the PCB. This is the most space-saving solution and also best for noise and stability.
Ambient light tight protection also from rear side is absolutely necessary. If not, the tube will get damaged, when operated.

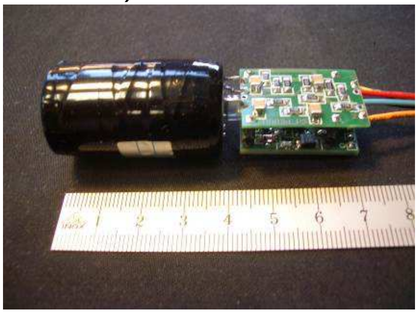
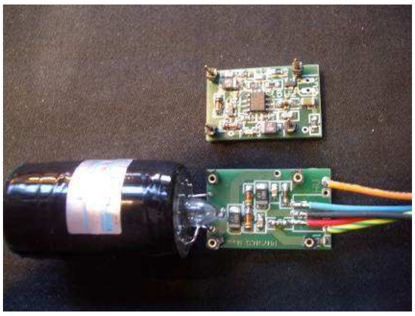
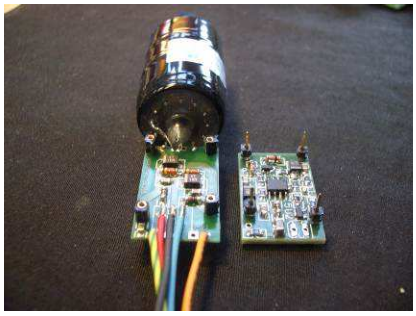
4. Assembling VPT/VPTT

To achieve maximum flexibility in connecting the different photodetectors and mechanical construction, the two PCB's of the preamp are delivered separately and have to be soldered together with four solder joints by the user. Several variants are possible:

Variant 1: VPT soldered via litz wire

Variant 2: VPT soldered to Preamp with a PCB-distance of 4mm (overall length: ca.78mm)

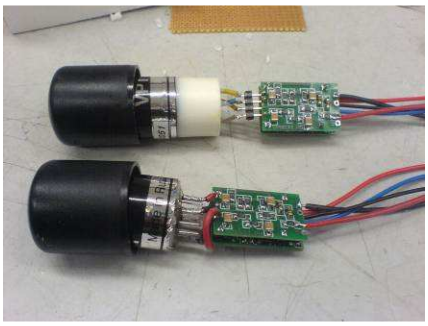
Variant 3: VPT soldered close to Preamp with a PCB-distance of 10mm (overall length: ca.73mm), see Photos below

Length of Preamp+R11375MOD Hamamatsu-Tubes: 73mm (with very carefull handling down to 70mm) if distance of PCB's is 8-10mm (the glass exhaust is then overlapped by both Preamp-PCBs).

If you choose a 4 mm PCB-distance, the overall length is then 5mm more, let's say around >75mm.

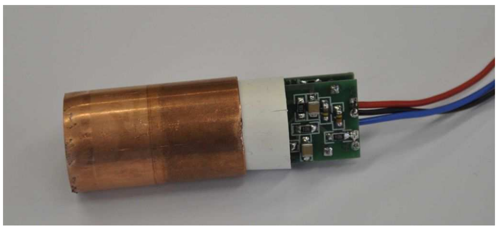
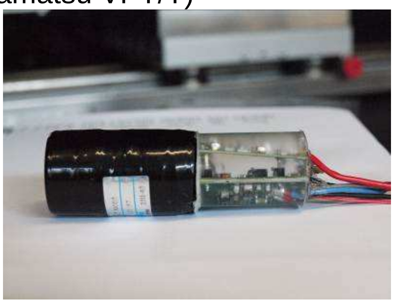
b.) The Hamamatsu R2148 and the RIE-Tetrodes (without silicone potting) are tubes with a pin-socket, which allows proper space-saving construction, f.e. via a socket or direct soldering to a disc-shaped interconnection-PCB.

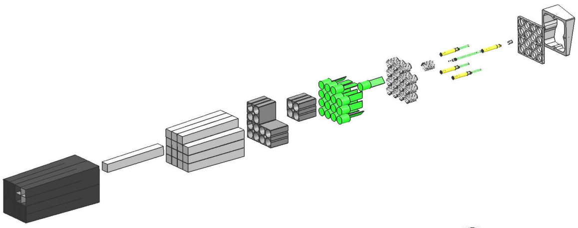


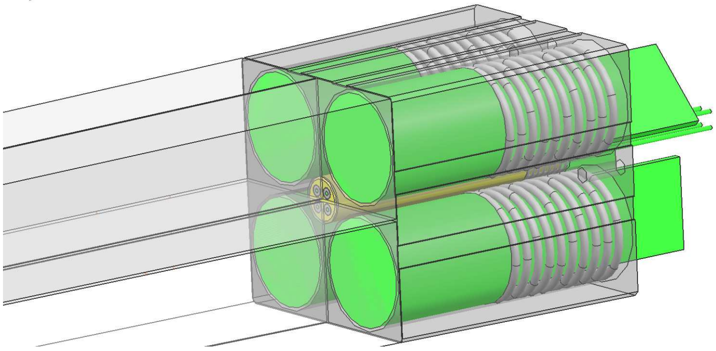

Left: comparison with/without silicone for RIE VPTT (Photo: Tomas Held, RUB)

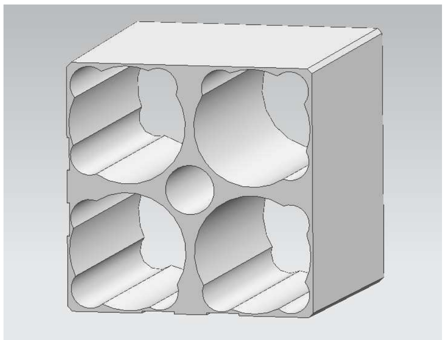
Right: VPTT (RIE) „bare“ (without silicone), 2 unused pins cutted

Below: Universität Bochum (with Hamamatsu VPT/T)

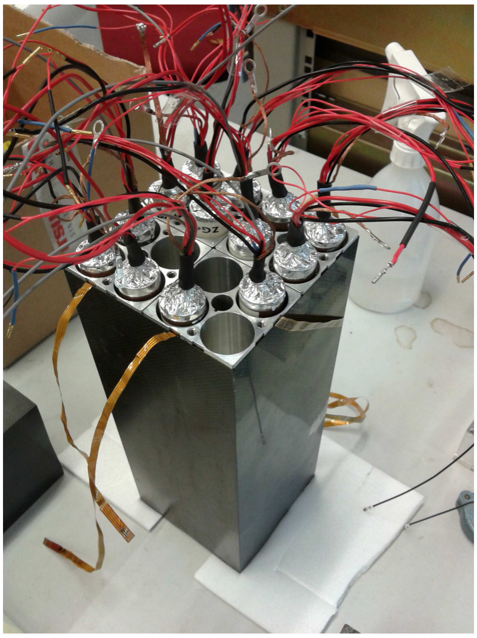



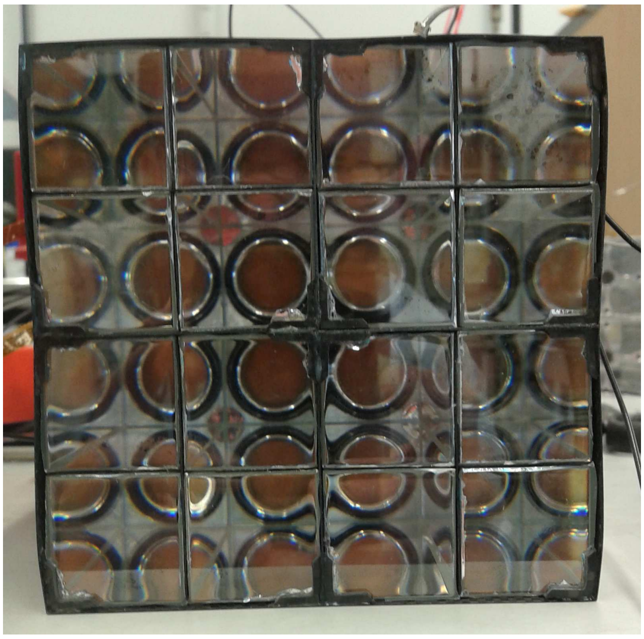






2012

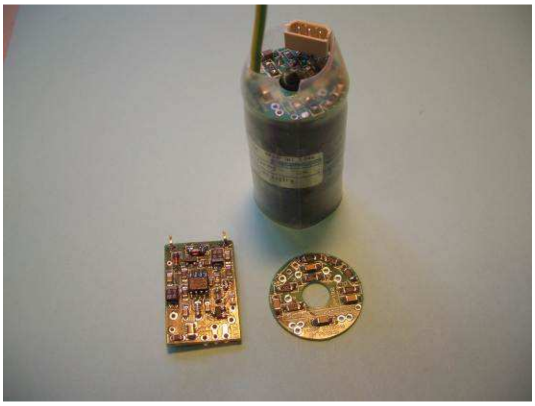
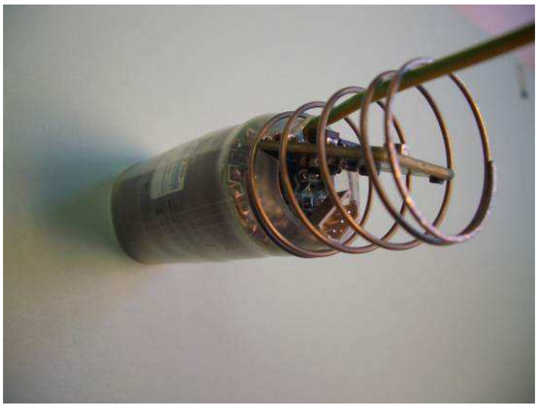




4.a. Assembling VPT/VPTT, (new) Version with round HV

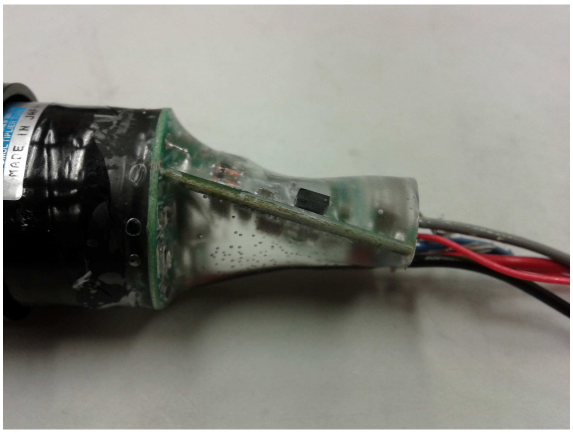
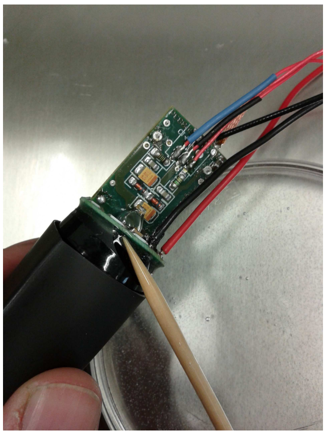
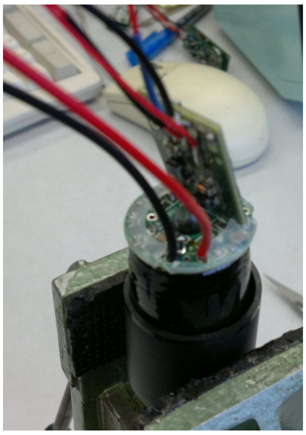
New features to improve manufacturing and stability of Hamamatsu-tubes:

- Round HV-PCB for Hamamatsu VPT or VPTT (RIE has different Pin configuration)
- alternative HV-Connector Molex Spox (coded, locked) for HV connection (cut one edge)

1. Abrade 1mm of PCB from Preamplifier-PCB carefully or mount the PCB transversal
2. Solder in wires and Preamp-PCB justified into the round HV-PCB
3. Solder HV-PCB to the VPT/T
4. Glue PCB with small amount of non-corrosive silicone (as Dow Corning 3145 RTV) o the VPT/T
5. 60mm shrinking tube Ø=24 mm onto the tube with HV-PCB or kapton tape to isolate the HV
6. Wrap around 78mm self adhesive Alu-foil (sized 50mm or even better more, f.e. Tesa 50575)

Example, see also: http://www.bonner.rice.edu/~jhzhou/up_pvpd/construction.html

5. Adapter-PCB for Dual APD/crystal

For "short" preamplifier SP883d (might be usefull also for "long" version SP883a02)
An additional ca. 18x18x1.6mm (depends on capsule), double-sided PCB was built**.**

Features:

- Protects the APD-Pins when mounting/dismounting from the crystals
- Planar mounting of the APD-frontsurface (equalize differences through mounting aid, then solder and glue it to the PCB).
- Holds the two preamplifiers to the capsule
- Holds HV-Filter and Connector for APD
- Connection and filtering for both HV's
- GND-Plane of Dual APD-PCB is the 6th side of the electromagnetic shield!
- Could be soldered to copper tube (via two 2mm holes)
- Temperature shield (decoupling)/radiation barrier (similar as in Proto60)

Glueing the APD to the PCB: maybe with an additional soft silicone sheet (removable?)

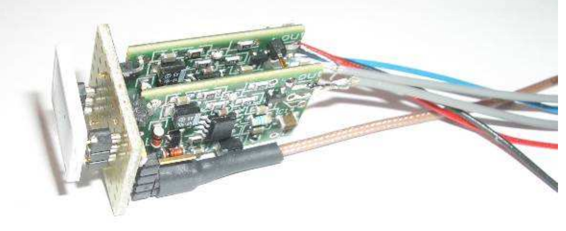
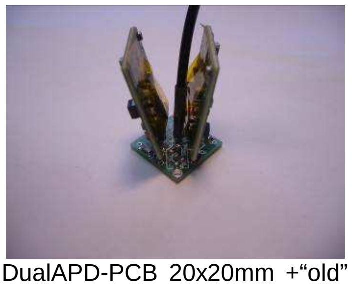



Photo left: two "short" preamps SP883d+prototype DualAPD-PCB 20x20mm +"old" quadratic APD in a socket + cables
Photo right: two "short" preamps SSP883d+dual APD adapter SP883d_APD 18x18mm, with a HV-Cable RG174

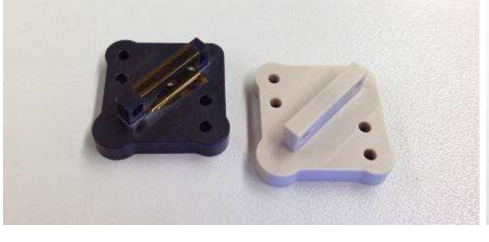
Mounting of SP883a02 ("long")



5.a. New Capsule, with Preamp-holder

An improved version with a Pramp-Holder made out of PEEK was designed an manufactured 2012.
The (black) PEEK CF30 material was replaced by the natural PEEK because of the unneeded electrical conductivity through the carbon fibres. PEEK has better resistivity to radiation than POM, but is expensive and difficult to proceed. The separating divider bar is omitted in the latest version.

The depth of the APD-„bed" is slightly smaller to allow the APD to make full contact to the crystal.


Photos:
black PEEK CF30-Prototypes (not used) with modification and isolation,
natural PEEK: latest version

Operating Temperature

The lower the temperature (typ. -25℃), the lower the noise of the system.

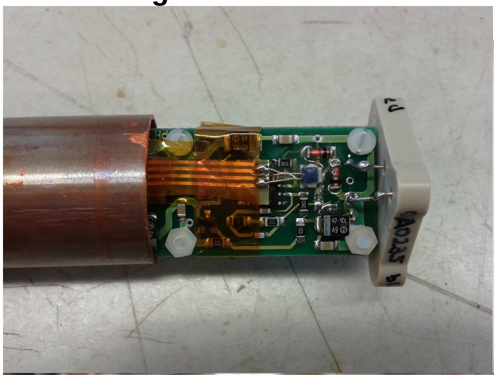
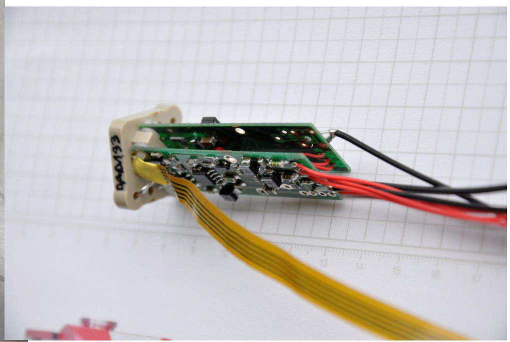
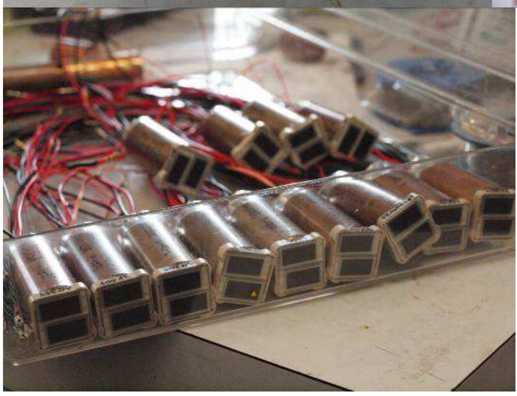
Please note, that for a constant internal APD-gain (M) the APD voltages must be decreased while decreasing the temperature. This is due to the temperature dependence of the gain vs. reverse voltage of the APD; see the graph of the APD data sheet. Each APD has to be controlled individually.

Soldering the APD

Solder the APD with high care:

- Short time heating
- Solder the APD with leaded
- ESD-Protection

Assembling 2012 for Proto192

Filter and decoupling

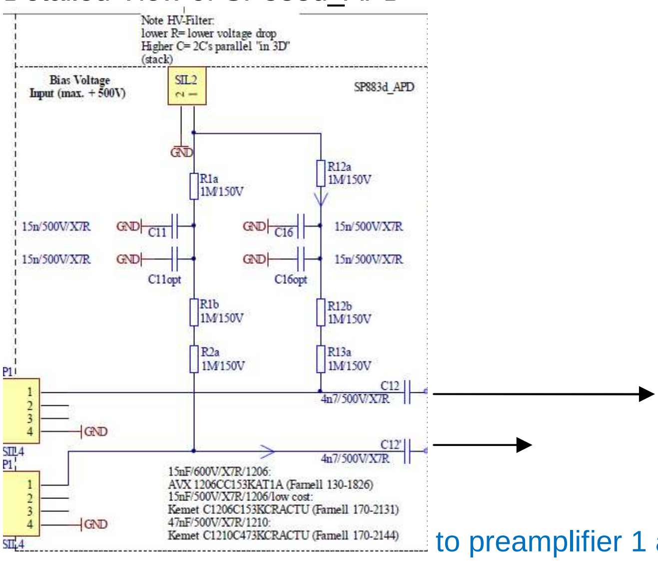
The APD bias voltage is low-pass (LP) filtered by a 10 Meg Ohm resistor and a 4.7 nF high voltage (HV) capacitor which results in a cut-off frequency of 3.4 Hz. After this LP filter the bias voltage is fed via a 22 Meg Ohm resistor to the cathode of the APD; the anode of the APD is wired to ground. The gate input of the J-FET is also decoupled by a 4.7 nF high HV capacitor. A maximum APD bias voltage of +500 V can be applied and the total leakage current of the circuit under dry and clean conditions is below 2 nA.

As already discussed in the OVERVIEW (APD BIAS AT HIGH EVENT RATES) the voltage drop over the LP filter is critical at high event rates in combination with high energy; a maximum current of 140 nA is then flowing trough the APD. The actual series resistance of the LP filter is 32 Meg Ohm, resulting in a maximum voltage drop of 4.5 V. By applying the typical gain sensitivity of 3% per volt of the LAAPD, this voltage drop corresponds to an energy error of –13.5%, which is not acceptable (see *Figure 4*). Reducing the series resistance of the LP filter to 1 Meg Ohm will diminish this energy/rate error below –0.5%, but the noise of the preamplifier will increase by 15%. Using the same filter capacitor with 4.7 nF, the cut-off frequency will increase to 103 Hz; which will also worsen the noise performance. This cannot be exactly specified, because it is depending on the noise characteristics of the bias-voltage supply. Larger HV filter capacitors would consume more space on the PCB.

The change of the values for the HV-filter (3M instead of 32M and 15nF instead of 4n7) was made to decrease rate dependency of the bias voltage HV (and therefore APD-Gain).
Note: this reduction in bias voltage/gain dependency may result in a rate dependent temperature rise and therefore influence to the APD-Gain and crystal temperature!
The resistors are now 3x 1M/150V (total of 450V) in a 0805 case because of lack of space for the 2x 500V resistors in the 1206 case.
The reduced series filter resistance to reduce the bias voltage drop at high rates is partly compensated by a higher capacitor (15nF/500V in 1206 case, instead of 4,7nF). Additional capacitors on the external PCB might be usefull to keep low noise performance.

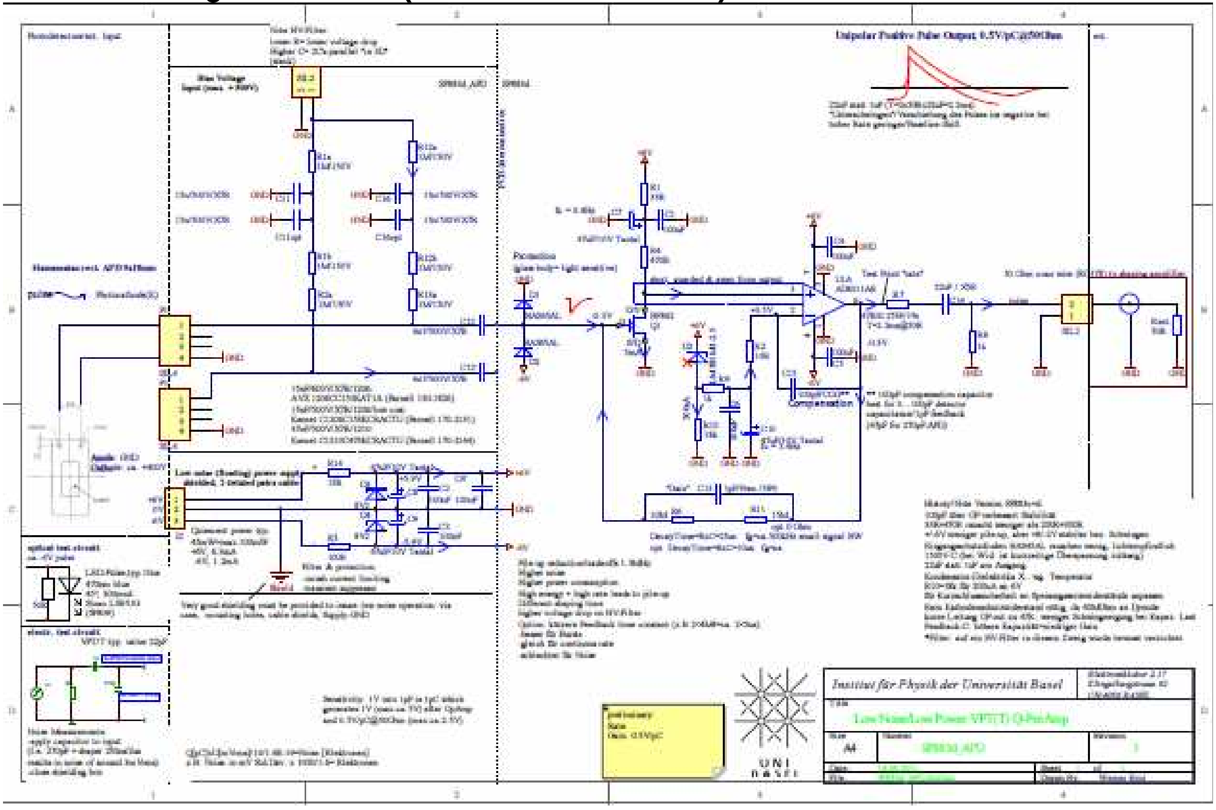
Differences	SP883a02	SP883a03	SP883d_APD
HV-Filter	32 MΩ/4,7nF	150kΩ/4,7nF	3 MΩ/15nF
Adapter	Filter on Preamp, not Adapter	Filter on Preamp, not Adapter	Filter on Adapter
Compensation	47pF	100pF	100pF

Detailed View of SP883d_APD



to preamplifier 1 and 2

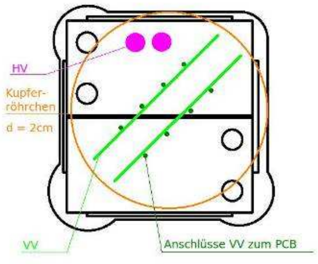
Schematic Diagram for APD (SP883d_APD+SP883d)

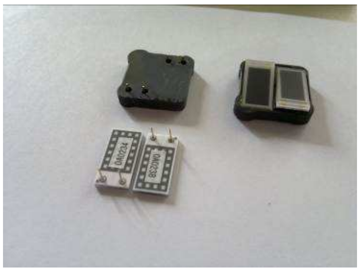
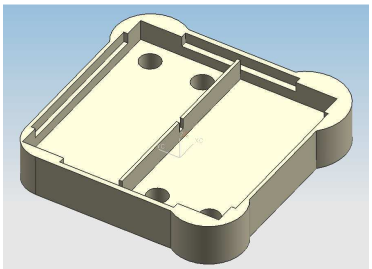


6. Capsule

The capsule works as mechanical interface for the APD's to the crystal. When mounting the APD's into the capsule, take care because the capsule reaches around 0.2mm over the APD.

Material: for Proto192 milled from POM, later for better radiation hardness PEEK is foreseen.



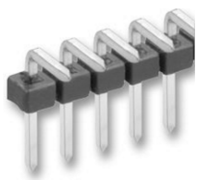
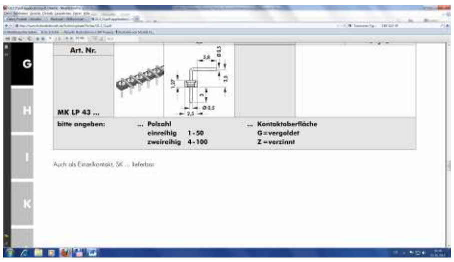
Note: The HV is soldered directly to the PCB (placed around the center of the PCB between the preamps). To save cabling, only one HV is available for both APD's. Therefore they must selected for gain-conformity.
The cabling for LV (+/-6V) can also be reduced when both preamps are interconnected.

The capsule and the Dual APD-PCB can be integrated optionally for high volume production as one unit made from Epoxy/FR4 as a "3D"-PCB. Also space can be saved that way.

The two holes with 2mm diameter are connected to GND and can be used to mount the copper tube or similar.

Connectors

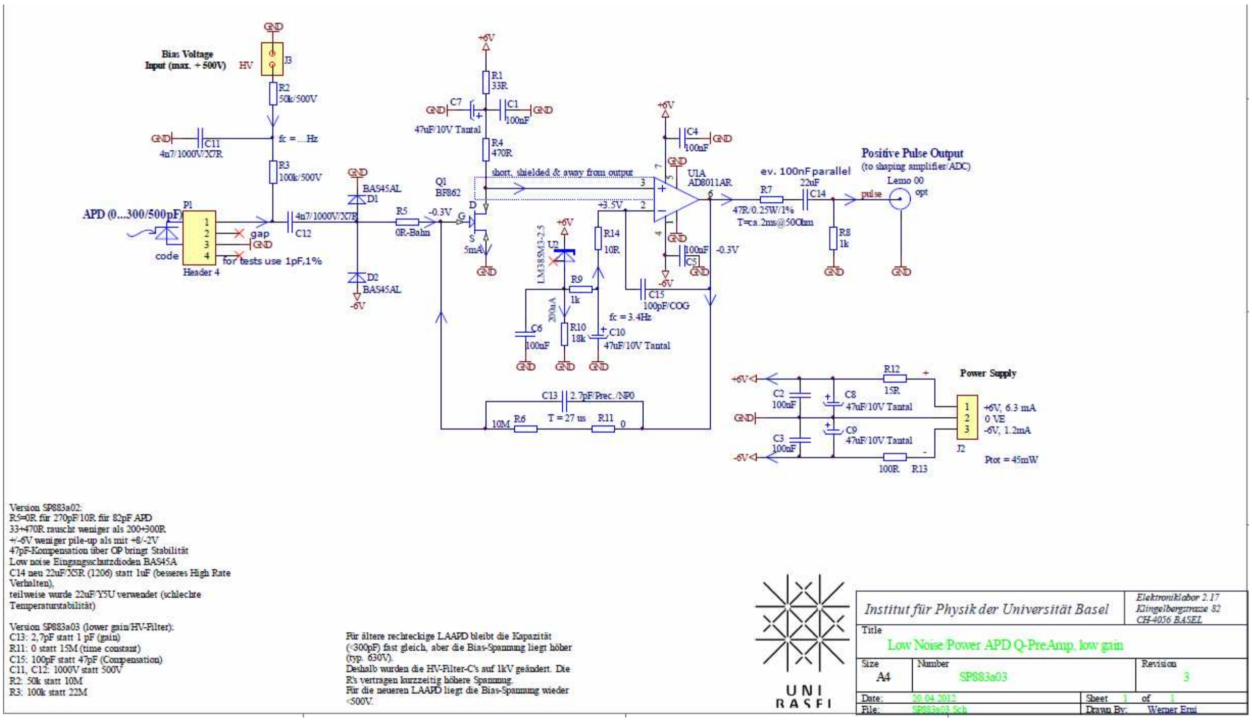
Contacting the preamps to the « Adapter-PCB » SP883d_APD is achieved by soldering the boards direct with a rigid wire or a 1 pin-connector (f.e. Farnell : 972-9151).
For SP883a02 („long") use Ø 0.5mm-rigid wire or 1 pin of the Fischer Elektronik MK LP 43.
Note: Solder the pins on the component side, because on the APD/Capsule-side is no space for pins or solder joints. So cut the pins in a way that they do not reach out of the PCB.

or alternatively with a connector :
Board to Board, 8 contact, single row 2mm-pitch connectors (male 90° THT, female: SMD)
Harwin Datamate L-Tek (f.e. Farnell: 177-6199/177-3791).
Molex Series 55932, shrouded header, Part-No. 0559320810

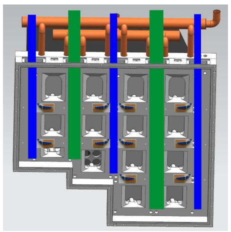
Version “Low Gain” APD (for Proto192, 2012)

SP883a03 is based on the the same PCB as Version SP883a02, but with some different components to reach lower gain (/2.5) and lower Filter resistance (Bias-HV dependency) for Proto192.
Filter:
R2 is now 50kOhm instead of 10MOhm and
R3 is now 100kOhm instead of 22MOhm
Gain:
C13 is now 2.7pF instead of 1pF
R11 is now 0 Ohm instead of 15MOhm
Compensation: C15 is now 100pF instead of 47pF

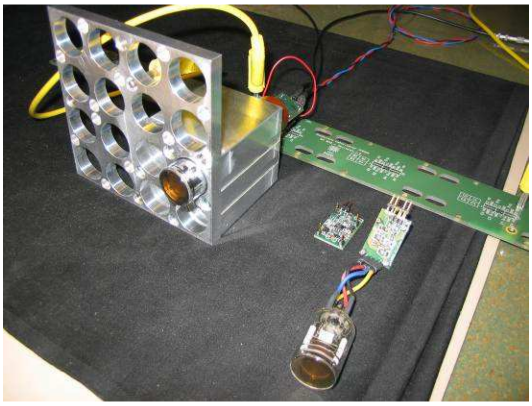


Distribution of Power Supplies

The distribution of LV and HV can be done via a PCB (Design by Mario Fink, Bochum)

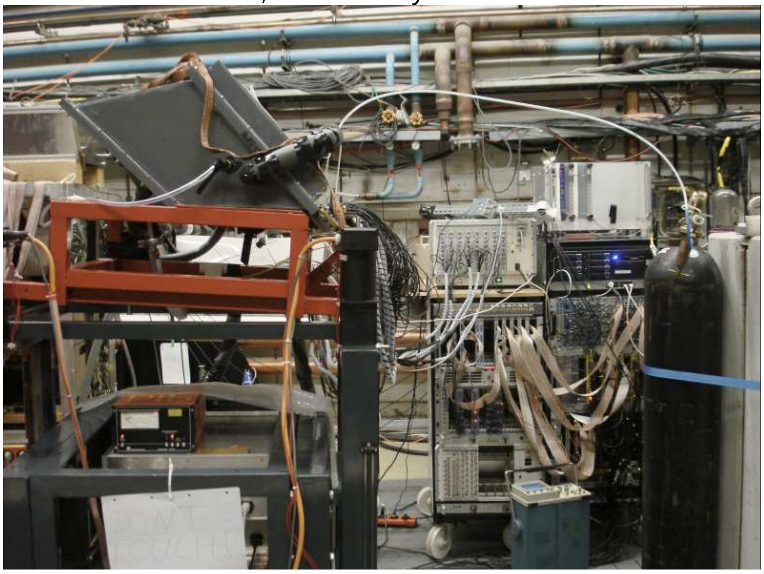


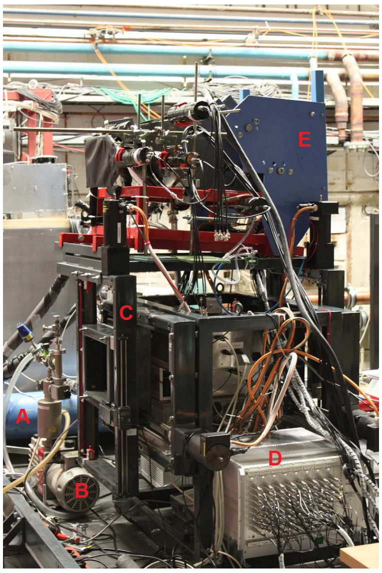
Below: Model SP903a for Proto60 shown in pictures) or as “daisy chain” via loose wires.



HV

HV-Crates from ISEG, controlled by EPICS via CAN-Bus





Left: Proto60 with HV; Right: Tests in Mainz; Tank with dry nitrogen gas (A), Vacuum pump (B), X-Y-Support (C), High Voltage Supply (D), Proto60 (E)

HV for Proto192

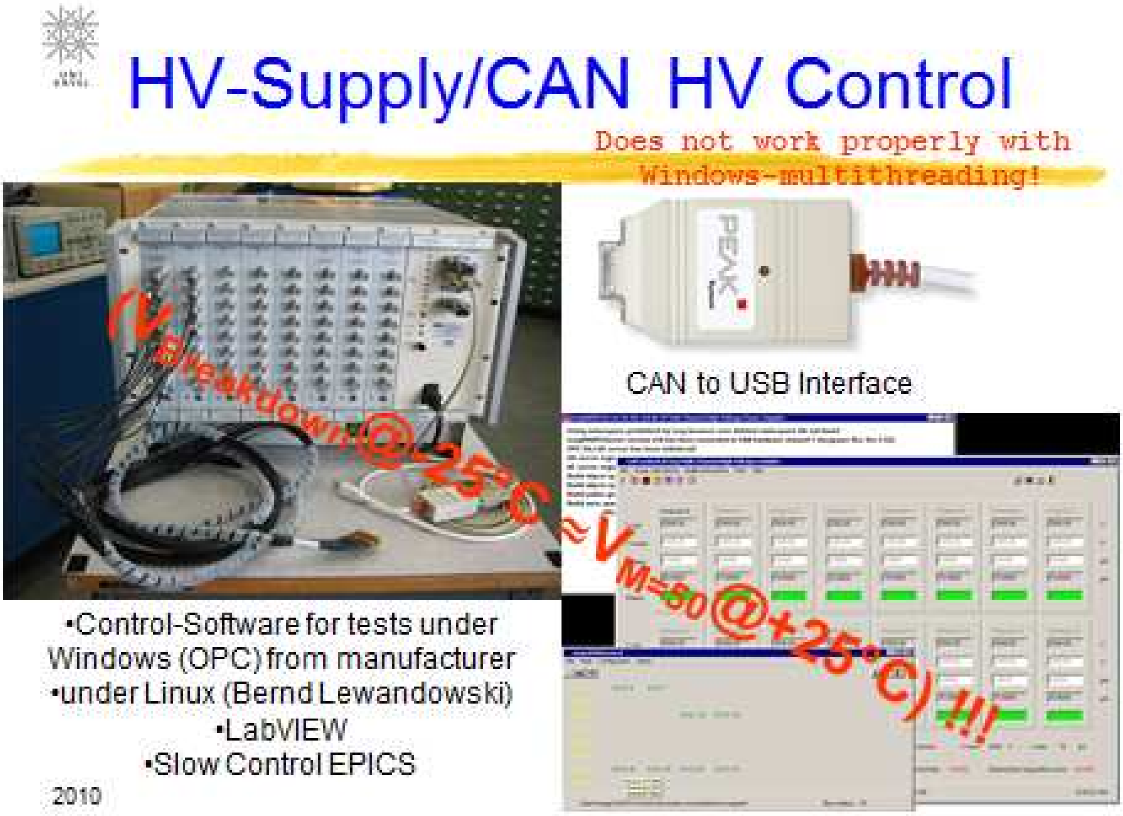
APD: HV-Module ISEG EHS8 210p-F, +1kV/8mA, High Precision
VPT/T: HV-Module ISEG EHS8 620p-F, +2kV/4mA
35 channels for VPT/T HV (sharing 1 HV among 4 channels) and 64 channels for APDs (sharing 1HV among 2 channels). Control Software is EPICS. Bus is CAN.

Test beam at Bonn is preliminary scheduled end of July 2011. Delivery by the end of June to Bochum:
5 HV modules ISEG for VPT/T use
8 HV modules ISEG for APD use
2 crates ISEG with CAN-Bus for the modules

Please note, that for a constant internal APD-gain (M) the APD voltages must be decreased if you decrease the temperature. This is due to the temperature dependence of the gain VS. reverse voltage of the APD; see the graph on page 2 on the attached S8664 APD data sheet. For further details contact Andrea Wilms.

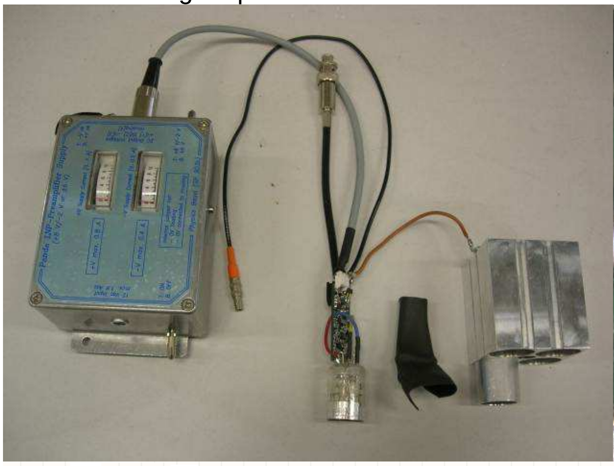
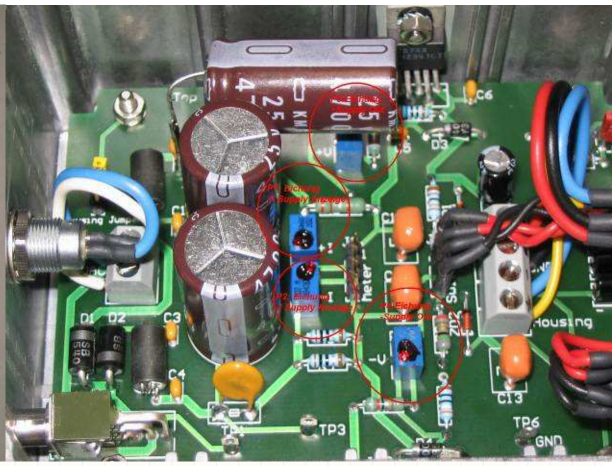
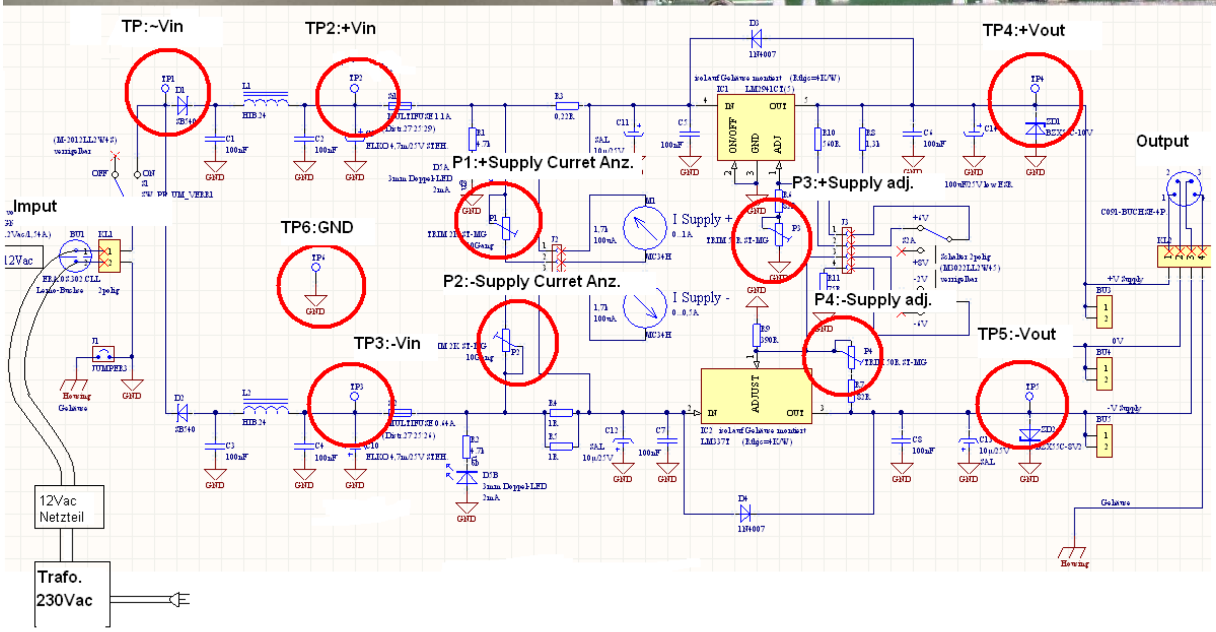
For the APDs we have measured, the reverse voltage had to be decreased about 10% to preserve the internal gain of M=50 between +25°C to -25°C. This was done by using a light-pulser system.

If you have a light-pulser system, you can easily adjust the APD reverse HVs at -25°C to get the same signals from the preamplifiers as you have measured before at room temperature.



LV (+/-6V or +8/-2V)

- Operation with +8/-2V limits the rate more than with +/-6V operation.
- Built in Basel dual DC output.
- Low noise, linear regulated
- Floating output

Power Supply type „Basel SP903b“ (shown in photo above) for up to 64 preamps at high rate (here with SP883c and VPT).

Alternatives

- +/-6V Adapter from NIM Crate
- Wiener mpod (control by EPICS via CAN-Bus)
- CAEN 8800
- other

Option: +10V/-2V Operation

Not recommended. Operation at absolute limits of Opamp with limited temperature range.
Increasing of output voltage with Trimmer possible, but generates more power loss in preamp.
Change Transformer (f.e. 15VAC/2A) to prevent from ripple at high load.
Desolder or replace Z-Diode BZX55C-10V with a 12V/10% type.

Pulse Processing

Signal chain

Photodetector	VPT	VPTT	APD
Photodetector Gain	6…10	ca. 15	50…100
Preamp output	+2.5V/50Ohm	+2.5V/50Ohm	+2.5V/50Ohm
Preamp „gain“	0.5V/pC	0.5V/pC	0.25V/pC or 0.1V/pC
Shaper, peaking time	650ns (Ti=250ns; Td=2us)	650ns (Ti=250ns; Td=2us)	650ns (Ti=250ns; Td=2us)
ADC input, single ended	Struck SIS3302	Struck SIS3302	Struck SIS3302

Spice Simulation

A precise Spice model of the LNP-Preamp including the shaping filter (peaking-time 650 ns) has been developed. Spice is the abbreviation for Simulation program with integrated circuit emphasis; it allows simulating an electronic system in the time domain (pulse response) as well as in the frequency domain (noise behavior).

Our circuit is based on the Spice models of the BF862 (March 2007, NXP Semiconductors) and the model of the AD8011 (Rev. A 1997, Analog Devices). The shaping filter is modeled noiseless by using the Laplace block from the analog behavioral modeling (ABM) library. All simulations are made with PSpice version 16.0 from the company Orcad/Cadence. The good agreement between the simulations and the measurements can be noticed in the *Figures 5* and *6*.

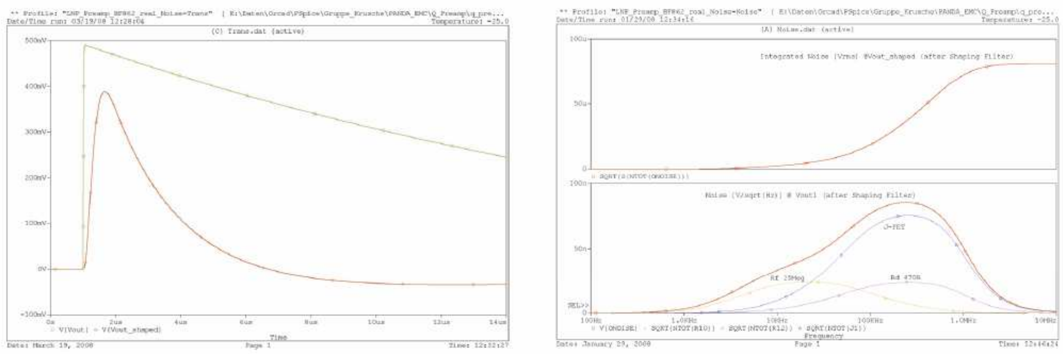


Figure 5: The left part shows the result of a PSpice time domain simulation with an input charge of 1 pC. In green the output signal from the LNP-Preamp (Vout peak = 500 mV_p) and in red the pulse after the shaping filter (Vout_shaped = 390 mV_p) is plotted; the shaping filter has a peaking time of 650 ns. The right graph illustrates a noise simulation in the frequency domain with a detector capacitance of 270 pF. With the curves in the lower part, the impact of the different noise sources to the total output noise (in red) can be studied; the y-axis is a noise density with the unit V/sqrt(Hz). It is obvious that the noise from the J-FET is the dominating noise source. The red curve in the upper part is the integrated output noise which results in 82 μV_{RMS}. This value in respect to the 390 mV_p for an input charge of 1 pC corresponds to a simulated ENC of 1'300 e^-_{RMS}, which is in very good agreement with the measurement. Notice that the temperature of the simulation, as well as the noise measurements, is performed at –25°C.

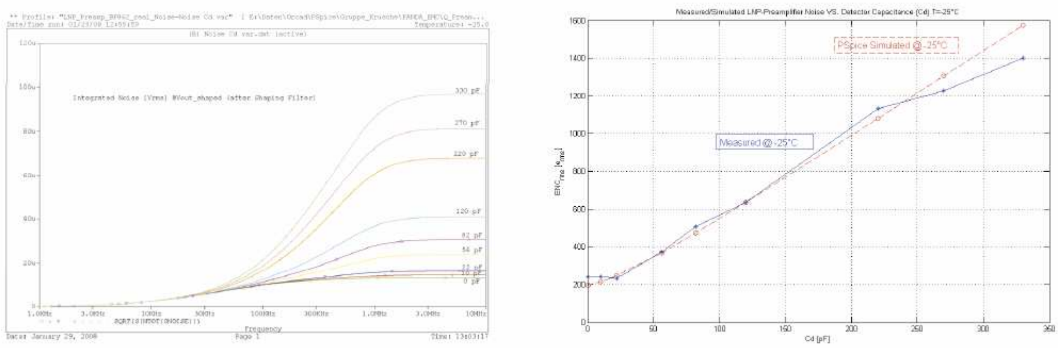


Figure 6: The left graph displays the PSpice simulated integrated output noise of the LNP-Preamp for different detector capacitances from 0 pF …330 pF. The right plot shows the simulated ENC versus the detector capacitance (dashed red) together with the measured ENC (blue line); both at –25°C. Over the whole capacitance range the simulation and the measurement are in very good agreement.

Gain

The gain was set equal for all models. In peripheral regions of Proto192 (and FW endcap) APD's are used. The gain for these photodetectors is typ. 50 < max. 100. If the bias voltage is individually regulated for both APD, a wider range can be covered in each crystal.
For use with APD with high gains, the gain of the preamp can be reduced, through changing the feedback capacitor from 1pF to 2 pF, but the compensation capacitor must then also be changed from 47pF to 100pF to maintain stability at lower temperature.
With VPT/T in the center of the FW-Endcap the output signal with 15GeV is expected around 1V (depending on Gain of photodetectors).

Dynamic Range

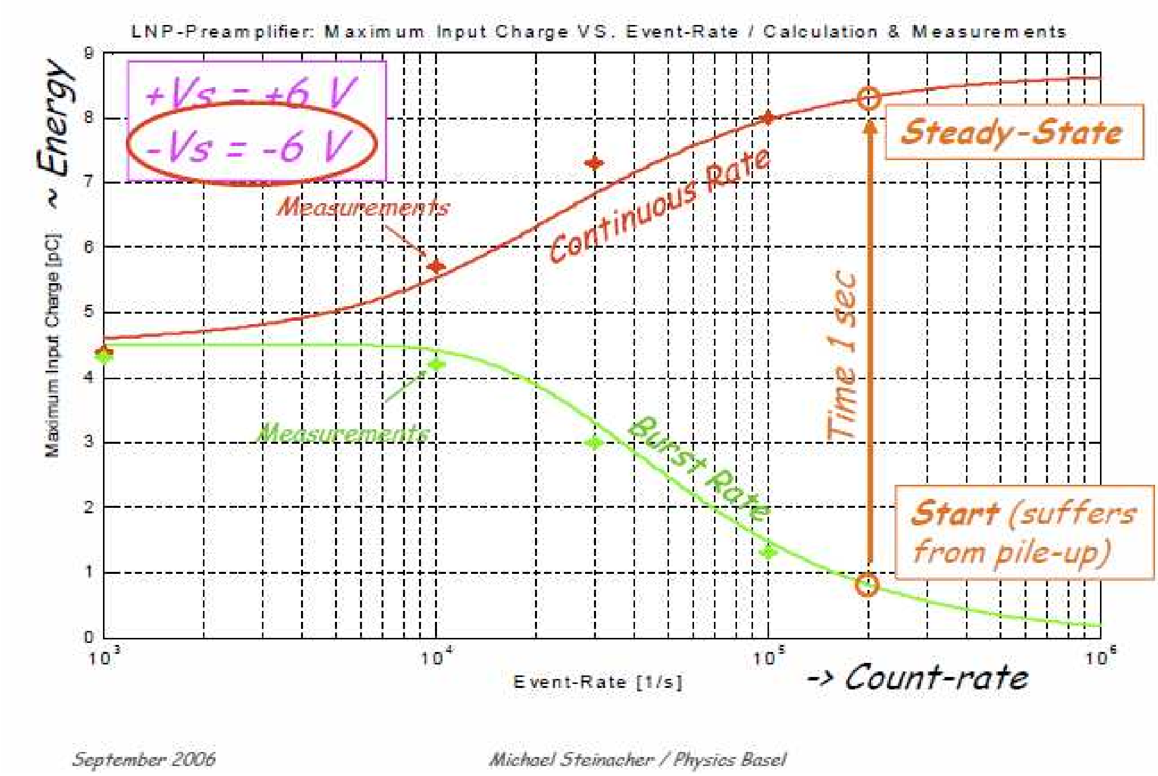
The lower end of the dynamic range of the preamp/photodetector system is given by the noise floor of the readout chain. The upper end is limited by the positive power supply voltage of the preamp.
In areas where much light is arriving (at high energies), the gain of the photodetectors can be reduced. The gain of the photodetector is varied simply by the bias supply voltage (via slow control system). This way different gains for different regions of the EMC can be achieved simply by calibration and controlled by the slow control as wished.
Where the gain of the photodetector itself should not be reduced, the gain oft he preamp can be reduced by modifying the component values in the circuit.
To increase the output voltage range operation with +8V/-2V (max.+10V/-2V) is possible.

Rate

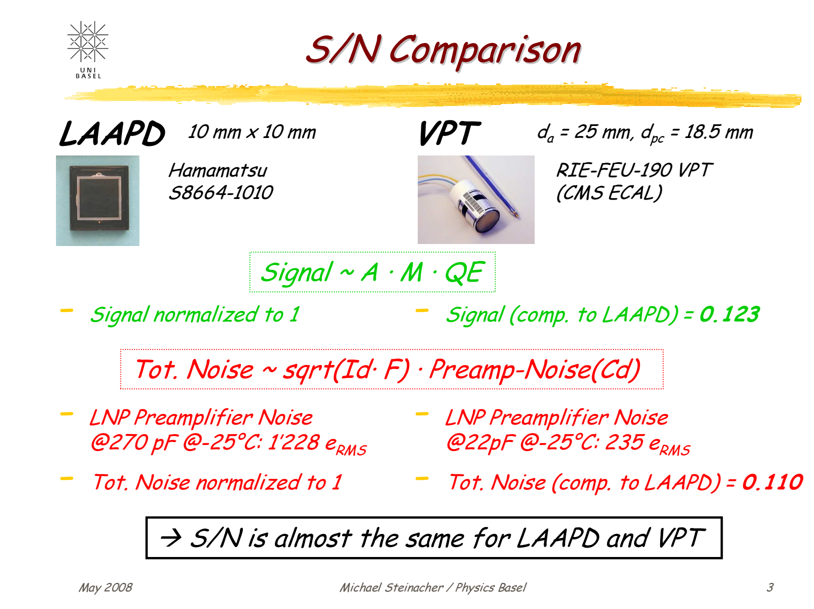
Quiet high continous rates (see plot below) are possible, especially at low energies (low charge), but is always limited by pile-up.
To cope with the expected event rates in the barrel of maximum 100 kHz per crystal, the LNP-Preamp has a concerted feedback time constant of 25 µs. This feedback time constant is a trade-off between noise performance and pile-up problematic.
For a single pulse (or very low rates) the LNP-Preamp accepts an input charge of up to 4 pC; for a continuous event rate of 100 kHz an input charge of up to 8 pC is allowed. This discrepancy is due to the following reason: A single output pulse starts from zero output voltage and is limited by the positive supply voltage (+6V) of the LNP-Preamp. At high continuous event rates the output pulses will swing between the negative (–6V) and the positive (+6V) supply voltage; therefore the maximum input charge is doubled. If a 100 kHz event rate is applied abruptly (burst) to the LNP-Preamp it takes around one second until a continuous input charge of up to 8 pC is allowed. During that transition period, a maximum input charge of 1 pC can be handled. With this charge restriction, the output voltage of the preamplifier stays always in the linear range and is never limited from the power supply voltages. Nevertheless, the electronics after the preamplifier has to perform a good base-line correction, because at higher rates it is likely that one pulse sits on the trailing edge of the previous one.
The operation with power supply voltages of +8/-2V limits the rate more than with +/-6V operation.

Pile-up

High energy at high rate leads to pile-up.
The "long tail" of the LNP-Preamp output is determined by the feedback-network (1 pF // 25 MegOhm) of the charge preamplifier. The resulting 25 us are a compromise between low-noise performance and high-rate capability (pile-up). In principle the time-constant can be reduced, but results in more noise (at least if you use a shaping-time of around 700 ns). The shaper after the preamplifier can reduce this fall-time without any problems as long as the preamp doesn't run into saturation due to pile-up.
The "undershoot" of the signal results from the AC-coupling (22 uF) at the output of the LNP-Preamplifier. Proper adjusting of the shaper eliminates this "undershoot".



Signal to Noise ratio



Noise vs. Cooling vs. detector capacitance

Data from Panda TDR, March 2008 with SP883a02

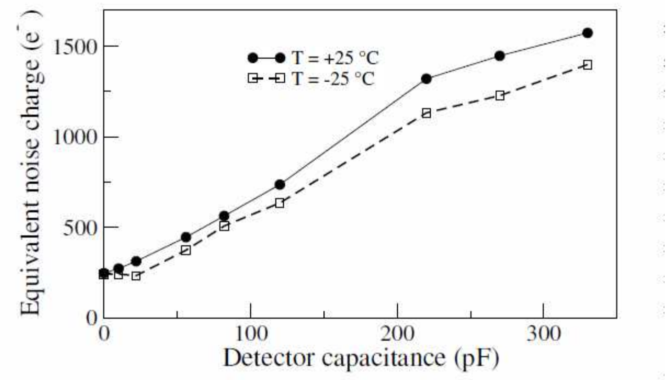
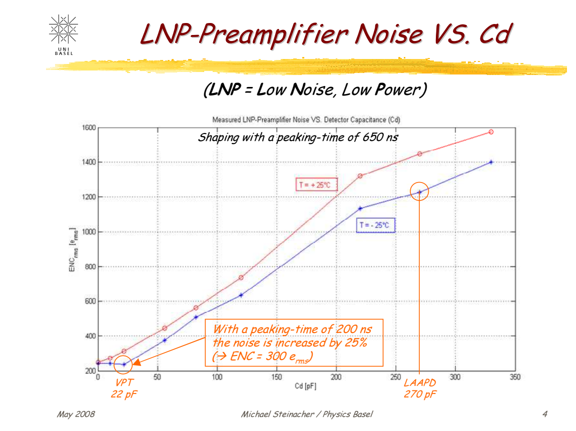
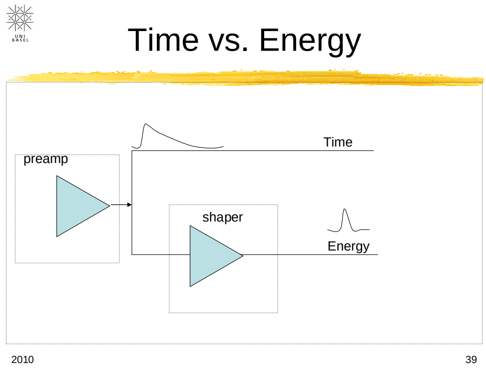
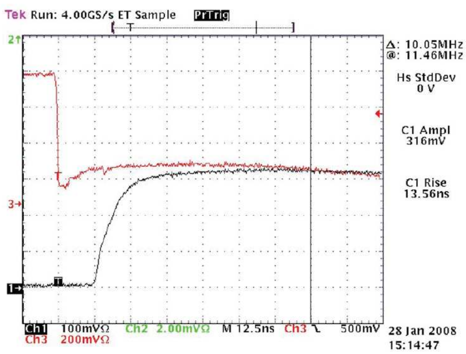


Figure 14: The measured noise performance of the LNP as function of the detector capacitance (C_d) at room temperature and at -25°C. Measurements are performed by using an ORTEC 450 Research Amplifier with an integration time constant T_{int} = 250 ns and a differentiation time constant T_{diff} = 2 μs, which corresponds to a peaking-time of 650 ns.

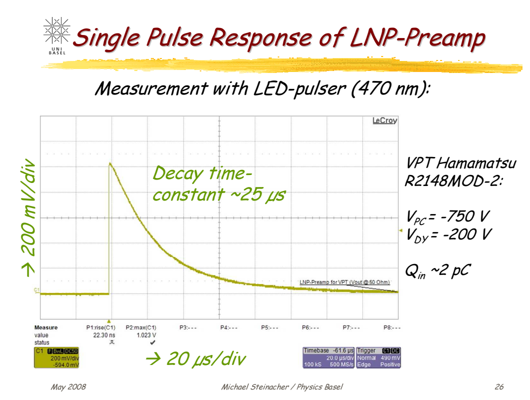


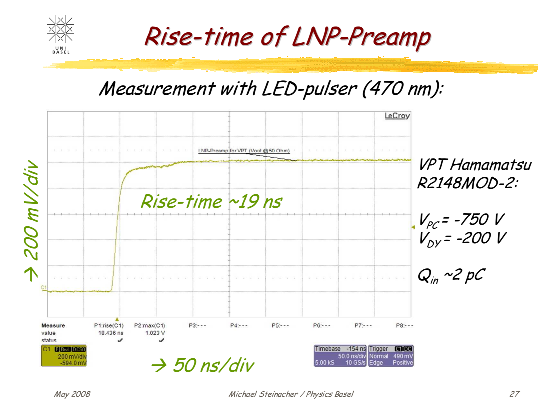
Rise Time/Timing Information



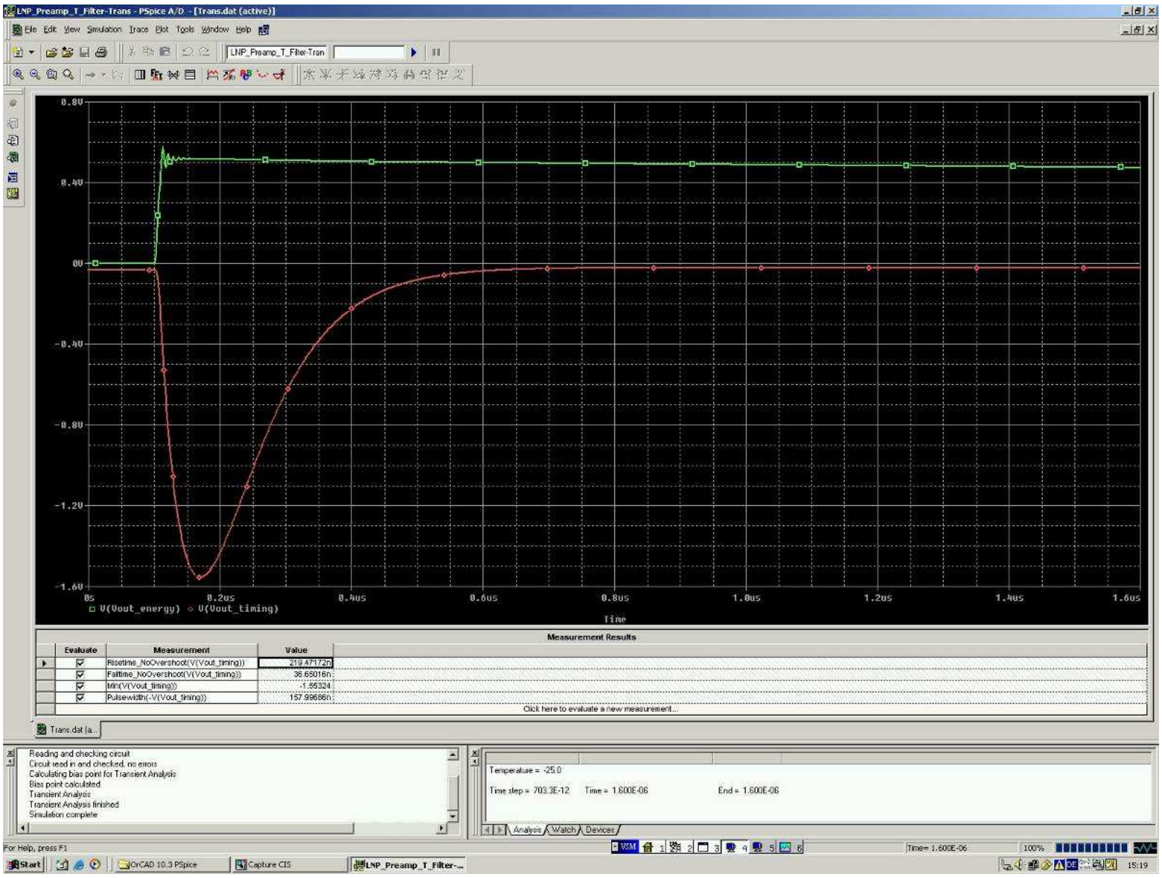


Precise time information





Simulation



Cable

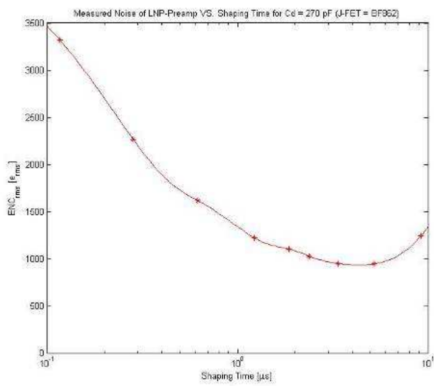
Low Noise 50Ω Coax Cable Ø1.8mm, Huber + Suhner K 01252HK-06 (green colour)
Signal Connector: IPX; U.FL; Amphenol-Typ**:** A-1PA-113-200G1 (Distrelec 13 82 60) with a tail of 1.15mm coax or Farnell 168-8075 (cut the 300mm long 1.37mm coax cable in the mid, then you get two cables with one U.FL-connector each).
Other side Lemo00-connector, f.e. Typ 11_QLA-01-2-11/122_NE from Huber&Suhner
Option: For use with RG-178 cable, System MMT von Radiall might be usefull:
RADIALL - R210408012 Farnell Best.Nr.:3044154
RADIALL - R284008001 - KABEL, Farnell Best.Nr.:3044142

Shaper

If it is not possible to use a fast flash ADC to capture the signal, a shaper is needed for operation. To achieve lowest noise, the shaper must be optimized to the signal output of the preamplifier.

Specifications for Basel LNP preamplifiers SP883x:

Peaking time	650ns (Ti=250ns; Td=2us)
Input range 50Ω (HiZ)	0…+2.5V; 0…+5V (0…+5V; 0…+10V)
Gain ranges	for example: 0.5, 1, 2 and 4/8/16 (adjustable to photodetector)
Output range	depends on photodetector and ADC (polarity, single ended 50Ω, differential)



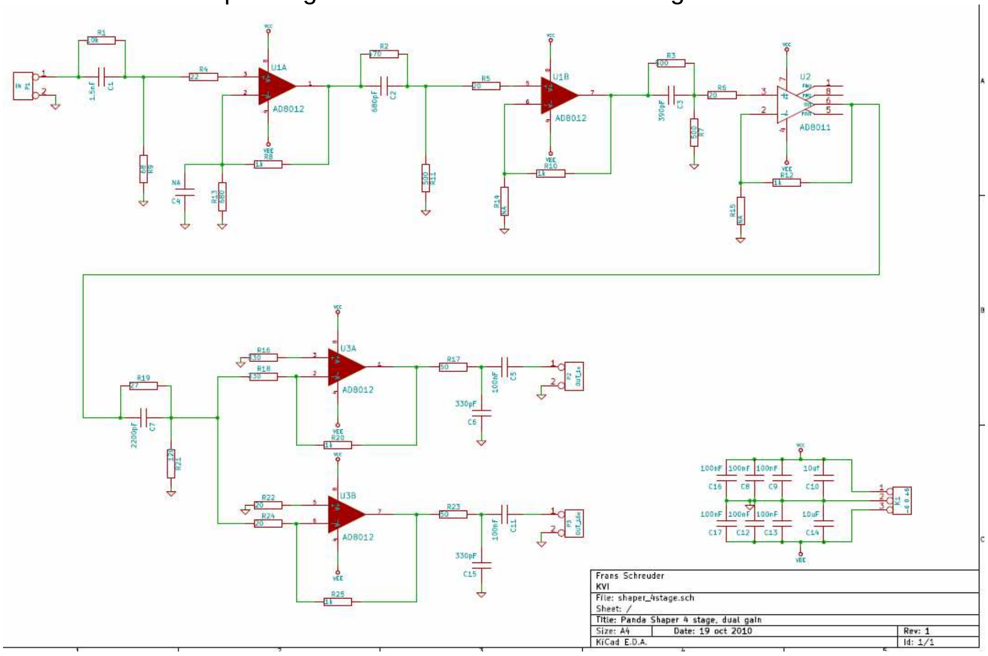
Possible additional shaper-feature options are:

- Signal polarity inverting (neg. output) and or differential driver to fit the ADC from Pawel Marciniewski.
- adj. gain (compensate VPT/T-gain) + multiple gain ranges (dynamic range)
- scaleable peaking time optimised in relation to the rate
- Baseline restoring

Note: Peaking time defines the time, the signal reaches its peak amplitude. Peaking time depends on integration/differentiation time, but is not the same as the integration time.
VME-crates with switch mode power supply usually generate more noise than NIM-Crates, both, radiated and conducted. Good filtering of the power supply tracks and shielding is important.

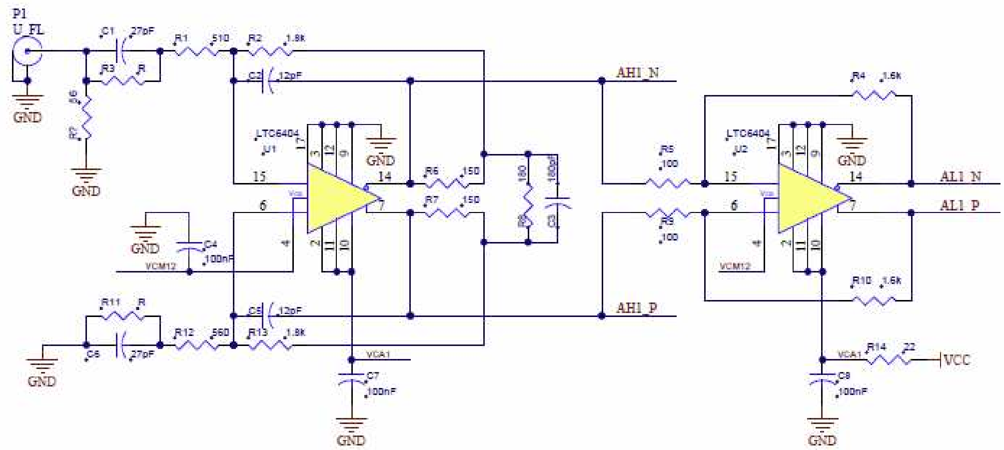
The “old” KVI-shaper (VME-module)

A 16ch. Shaping module was developed at KVI, Frans Schreuder in 2010 (MOD0111) and 10pcs. were produced. Powered by a VME connector (has to be modified).
Performance: The peaking time of 100ns results in too high noise. Crosstalk of around 10%.

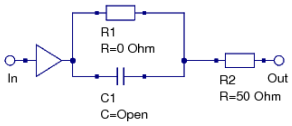


A comercially available 16ch. Shaper NIM-Module is the Mesytec MSCF-16.

The “new” KVI-shaper circuit (for implementation on the ADC)



Note: Passive „Preshaper” to shorten the pulse is not implemented, because this changes signal (energy) amplitude frequency dependent and output impedance and is therefore not well suited for the use in Panda.



drawing: KVI

ADC

Uppsala Pawel Marciniewski 100x162mm (Input matching via Shaper)/Wiener AVM16 (2V/50Ω single ended Input)

Recommended for Tests: FADC Struck SIS3302, 16 bit, 100MS/s, 8ch. (2.5V/50 Ω single ended input), VME

(with Proto 60 the peak sensing ADC CAEN V785N in combination with Mesytec MSCF-16 has been used)

Overview

	Wiener AVM16	Struck SIS9967	Struck SIS3302	Struck SIS3301	CAEN V1724
Resolution [bit]	12	14	16	14	14
Sampling Rate	160MHz	50 MS/s	100 MS/s	100 MS/s	100 MS/s
channel	16	16	8	8	8 single ended, 50Ω
Memory		-	32MS/ch	2x128kS/ch	
Input	2V/50Ω o. Diff. ?	5V or custom	+/-2.5V,50Ω/cust	2.5V, 50Ω or cust.	2.25V, 50Ω
Data	VME	Optical Link	VME	VME	VME
Price	7994 € (500€/ch)	4000 € (250€/ch)	5500 €	5000 €	3400 € (425€/ch)
Power	5V/4A	15-19.5V			5V/4.5A, +/-12V/0.2A

Wiener AVM16 Input circuit:

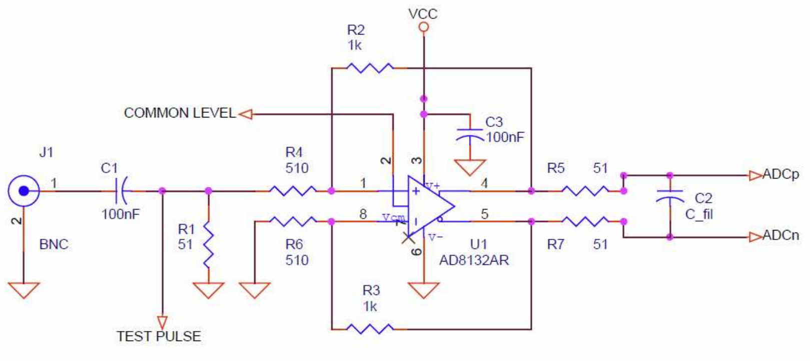
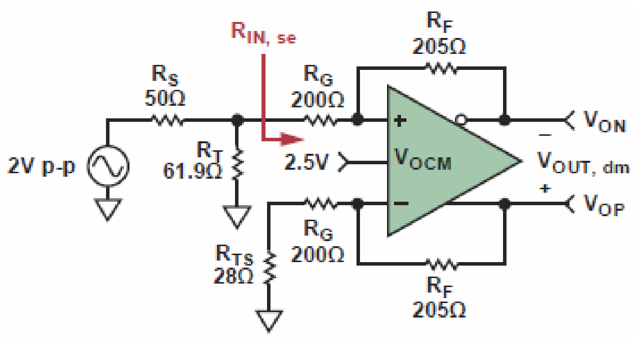
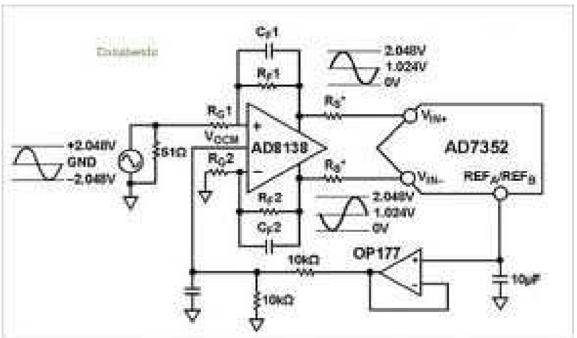


Figure 2: *Input symetrizing amplifier and anti-aliasing filter (R5, R7, C2)*

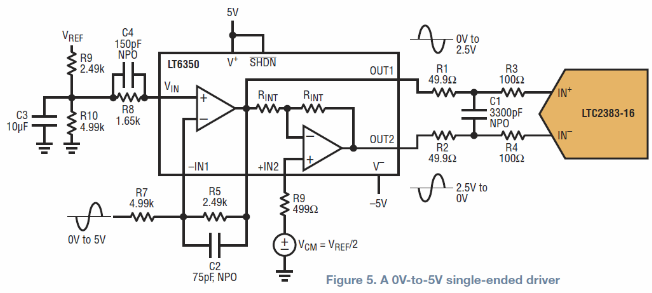
Matching (single ended to differential signal conversion)

Analog Devices AD8137/AD8139 (50Ω Input)





Linear Technology LT 6350 (High Z Input)



2011: LTC6403-1

Single ended to differential signal conversion with integrated LP-Filter (shaping)

LOW-PASS DIFFERENTIAL FILTER

Similar to an op amp, various types of active filters can be created with the AD8132. These can have single-ended inputs and differential outputs that can provide an antialias function when driving a differential ADC.

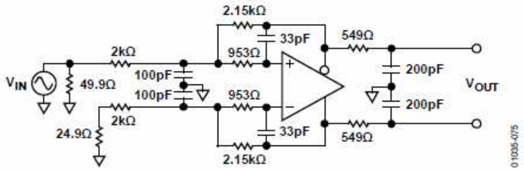
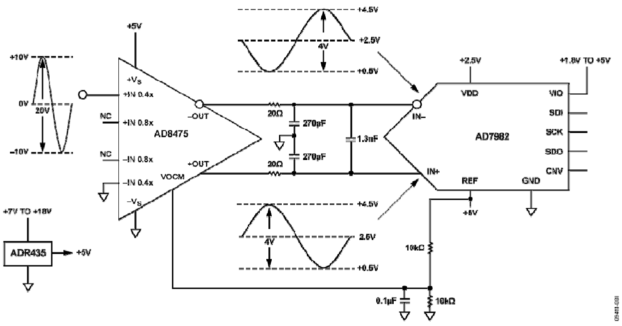


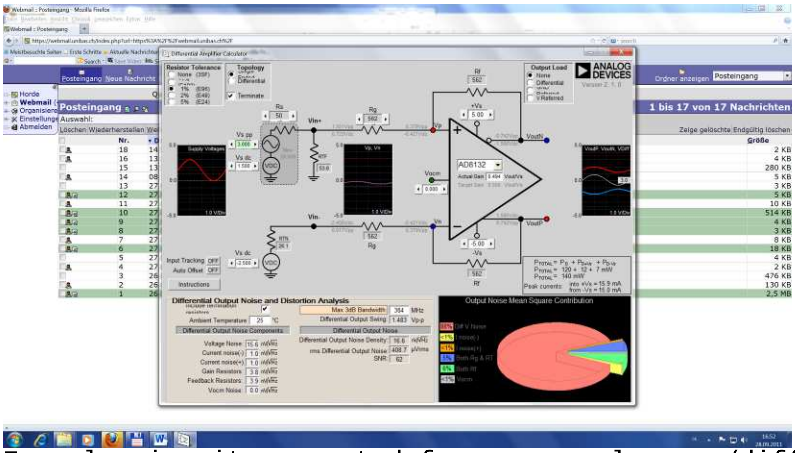
Figure 77. 1 MHz, 3-Pole Differential Output, Low-Pass, Multiple Feedback Filter

Figure 77 is a schematic of a low-pass, multiple feedback filter. The active section contains two poles, and an additional pole is added at the output. The filter was designed to have a −3 dB frequency of 1 MHz.

or



Opamps LT6202/LT6203
Diff Amps : LTC1992, LT1994



Example circuit generated from www.analog.com/diffampcalculator

Ortec applicaton note (passive):

Creating a Differential Output to Cancel Environmental Noise

When the coaxial cable connecting the preamplifier output to the shaping amplifier input is long and the cable runs through an electrically noisy environment, it is advantageous to employ differential signal transmission. Several amplifiers (Models 450, 671, 672, 973, and 973U) offer differential inputs for this purpose. A few preamplifiers include differential outputs to accommodate this function. If the preamplifier does not provide differential outputs, the box depicted in Figure 7 can be used to create a differential output.

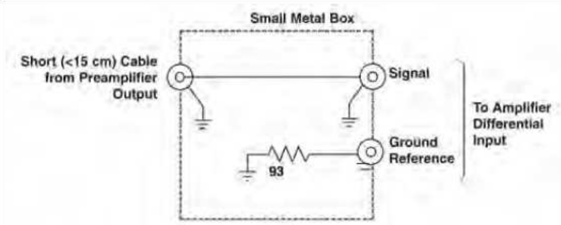


Fig. 7. An Add-On Box to Convert a Single Preamplifier Output to a Differential Output.

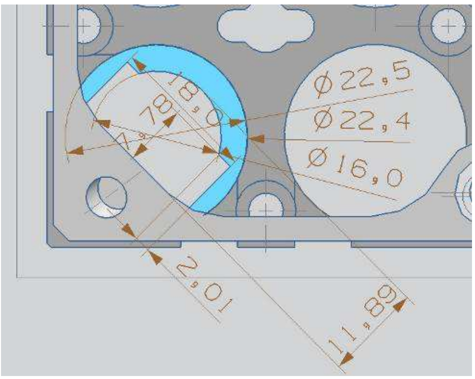
All the components shown in Figure 7 are mounted in a small metal box located close to the preamplifier. Care must be exercised to ensure low-impedance grounds. The input on the left side of the box is connected to the normal preamplifier signal output with a coaxial cable that is as short as possible. This short cable must provide a low impedance path from the preamplifier ground to the metal box. The center conductor of this short cable transmits the normal preamplifier output signal through the box to the normal input of the shaping amplifier. The 93-Ω resistor in the box is used to transmit the preamplifier ground signal to the differential reference input of the amplifier. Both the "normal" and the "differential reference" cables are RG-62A/U, 93-Ω coaxial cables. Thus, the 93-Ω resistor in the box provides reverse termination of the differential reference cable. This termination matches the 93-Ω reverse termination included inside the preamplifier for the normal output signal.

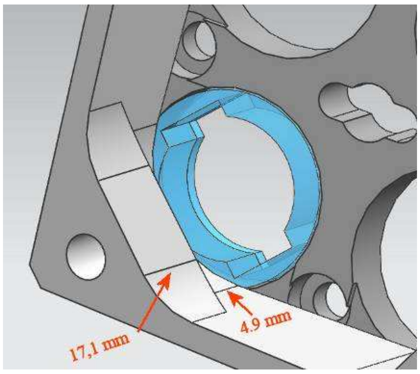
To ensure that both cables are affected in the same way by electrical interference, the two cables are twisted together in a spiral as they are routed to the amplifier. When connected to the amplifier inputs, the normal signal includes the desired preamplifier signal plus any interfering noise from ground loops or the environment. The differential reference signal includes only the interfering noise. Hence, when the amplifier subtracts the differential reference from the normal signal, the interfering noise is removed from the signal. Amplifiers with differential inputs usually incorporate a differential gain balancing adjustment to allow matching of the gains on the two inputs for exact cancellation of the interfering noise.

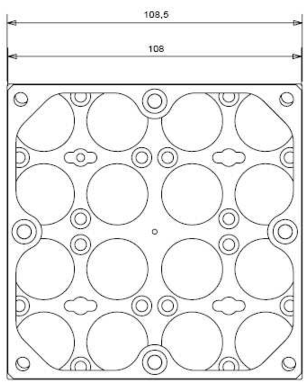
Slow Control (DCS)

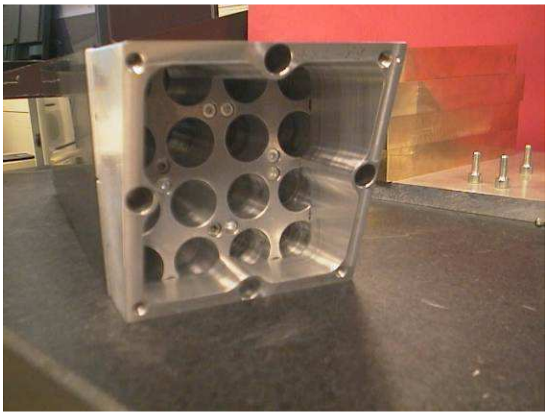
http://panda-wiki.gsi.de/cgi-bin/view/EMC/WebHome
EPICS is used, also for ISEG-HV

Mechanics









Drawings for Panda EMC Forwar Endcap Proto 192: Bochum Group

Crystal & Alveoles

Crystal Design: Tapered (11 different shapes) PWO crystals, Length 200mm, front face 20x20 mm2,



Foto right: Laminated carbon fibre alveole act as housing for this heavy load.

Silicone

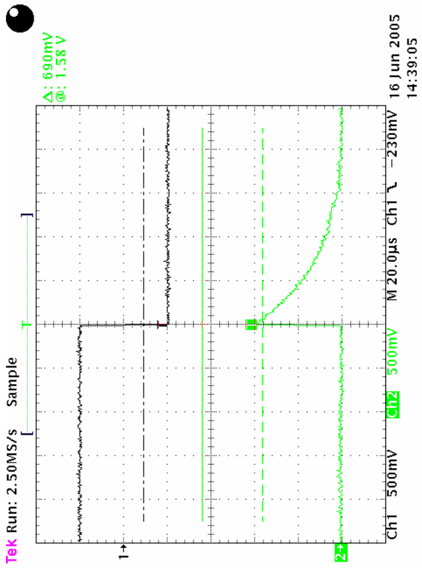
Non corrosive: Dow Corning 3145 RTV-Clear
2 component: Dow Corning Sylgard 184 to couple their scintillation detector assemblies

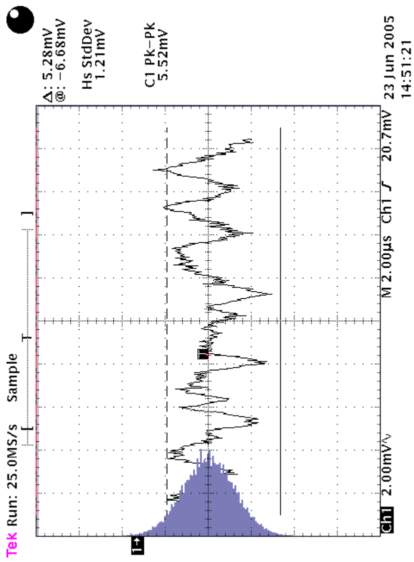
Optical coupling http://www.logwell.com/tech/servtips/optical_coupling_grease.html

Dow Corning Q2-3067
General Electric   GE G-688
Blue Star Silicones exclusively for Precision Converting Visilox V-788
Rexxon RX-688
Saint-Gobain/Bicron BC-630 (ähnlich GE G-688)
Nye Lubricants NyoGel OC-459.
Boro Technologies Boro 1000
Silicone Solutions Visilox "V-788" (SS-988)

Test Setup (Recommended)

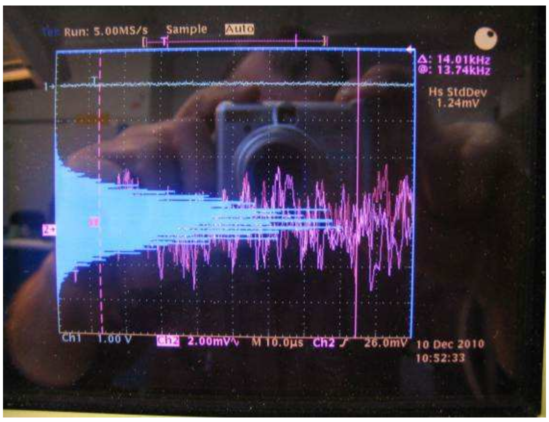
Instrument	Model/Type	Lab2.17-Nr.	Phys.-Nr.	Serie-Nr.
Testadapter (1pF/50Ω/270pF)	Own built			
Metal box	6-side			
Oscilloscope	Tektronix TDS784D	109		
Research Amplifier + 50Ω	Ortec 450		4257	783Rev.13
Float. HV–Source/Calibrator (not SRS PS325)	Fluke 341A	15		
Pulse Generator	HP 33120A	85		

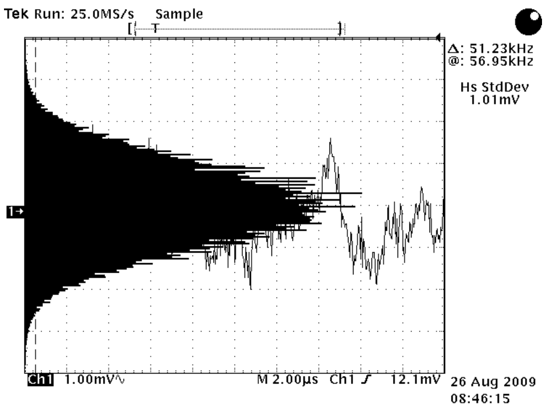
Pulse/Function: 

Noise: 

Prüfung	Serial-No.	Power consumption	Pulse/ Function	Noise w. VPT	Noise w. 270pF*	Leakage current	Auslieferung/ Bemerkung
25℃/"50% r.F."		*+6V/6mA -6V/1mA*	*(Ortec 450 kalibrieren)*	*[mV rms]*	*[mV rms]*	*[nA]*	
Histogramm				*Std. Dev.*	*Std. Dev.*		
Typical values	1	ok	10V	1.19*	3.0*		Rep/Juni 09

* Including noise floor of oscilloscope and shaper 0.5V rms





Reliability

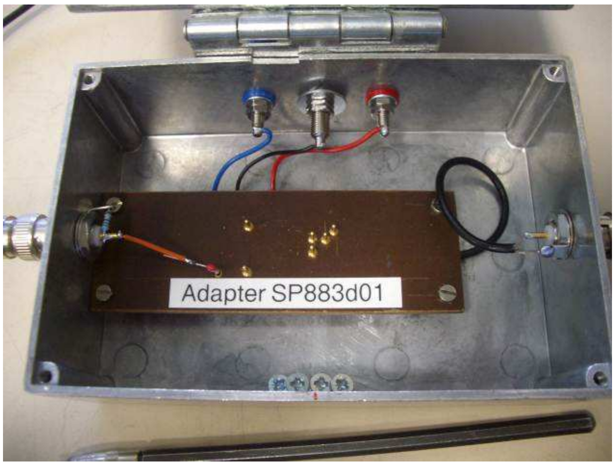
Quality

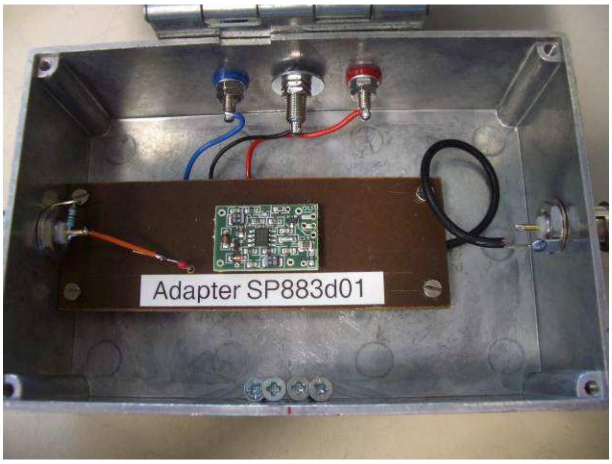
- 100% of the parts are tested for their function, but not for all parameters (f.e. temperature).
- After Testing, every unit gets its own serial number. It is a number beginning with 1, manually engraved on the PCB.
- We have not used leadfree solder to improve the long time continuous low temperature (-25℃) operation. We used a traditional Sn/Pb 60/40 alloy.
- Do not use halogenidated or chlorinated cleaning solvents as f.e. Trichlorethylen to prevent damage of solder joints through activation of “tin pest”. We use Inventec “Topklean EL 10F” for SP883d & Elma “Clean 225 Sonic” for SP883d_PS.
- Universal conformal coating for printed circuit boards « Plastik 70 ». A transparent acrylic resin based, transparent insulating coating. Protects against normal atmospheric influences. Soldering for repair is possible.
- Over 100 channels up to the year 2010 are in use at different sites/institutes, under different conditions (in beam, low temperature). Over 200 channels more will be built in at Bochum (Proto192) and Uppsala in 2011.
- In the past, defects occurred with FET’s and Tantalum Capacitors. Reliability can dramatically increased through prevention from ESD and other good handling practices.

Production tests

To test production volume of the electronic functions we have built a test adapter with spring contacts, because the pramps were built without connectors (wired).
Tests include:

1. power supply current, both +/- 6V
2. gain: calibration of the test instrument chain with pulse
3. noise output with 270pF at input





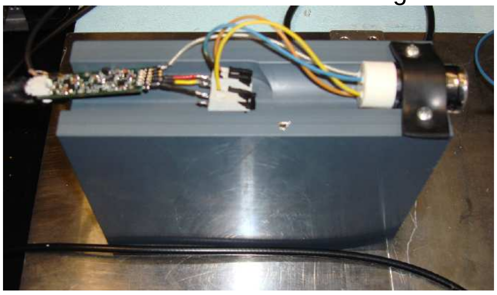
Radiation Hardness

Specially in the center of the Forward Endcap radiation is not negligible.
Tests in Spring 2010 at Mainz (Dr. Irakli Keshelashvili) showed that the Preamp will not be destroyed in a Beam. Online-Tests with quantisized radiation will be proceeded.

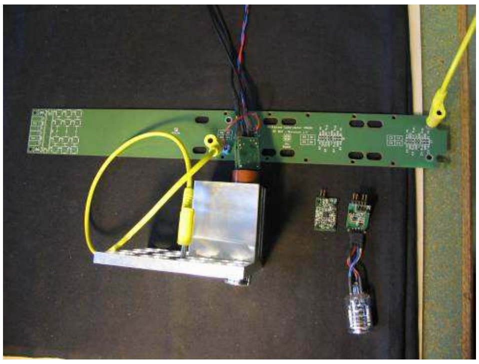
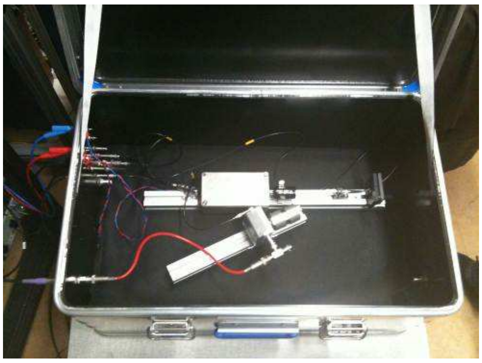
Addendum

Experimental Setup

Beware of Noise pick-up. The Preamplifier is a very sensitive instrument and therefore works similar to an antenna. For low noise operation, it is not recommended to operate the photodetectors and the preamp unshielded or in the same housing with motors.

Better:

Left: Distribution Board (6 Layer multilayer Board for LV & HV distribution with signal shield and matched 50 Ohm impedance); Right: light tight, shielded Alu-Box with LED & reference PMT

Measurements taken December, 17, 2010 @20℃, Preamp SP883d,S/N #3, with setup as shown above, GND-connection to Alubox,
Shaping with Ortec450, Gain=ca.x10, Ti=250ns, Td=2us
HV: 1100V from Fluke 341A

VPTT (RIE), no serial number. Prototype received March 2010 from Mr. Iouri Gousev/ RIE (no silicon/ Photosensitive area partially covered)

<table>
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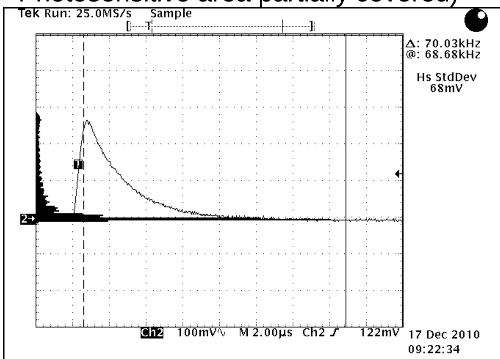
<td>
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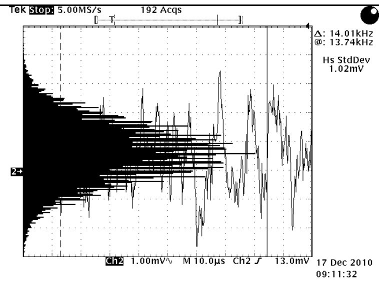
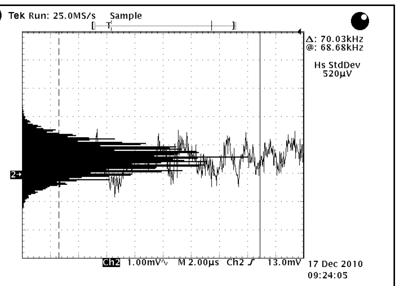
<td>


</td>
</tr>
<tr>
<td>above: VPTT (RIE), LED-Puls from SP771, optical coupling undefined</td>
<td>Left: Noise= sqrt (1^2mV–0.5^2mV)= ca.0.9mVrms/10/1.6E-19=562e-)

Right: Noise floor Ortec 450 with 50 ohms on input + KO;
No light to VPTT (RIE)</td>
</tr>
</table>

Beam Tests
In August 2011 tests are proceeded with a beam of 15GeV at CERN, October 2011 in Bonn and 2012 in Jülich.

Distribution of Power consumption
Most of the heat produced is coming from the FET. The power from the signal output is distributed half on board and the other half on the receiving side (over the 50 Ohm resistors).

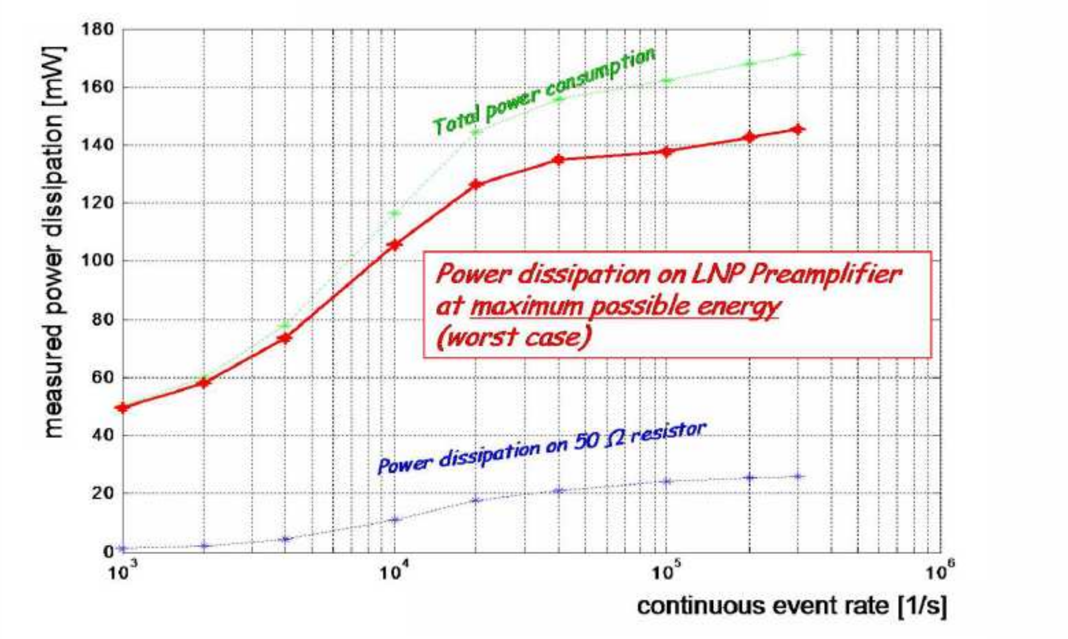
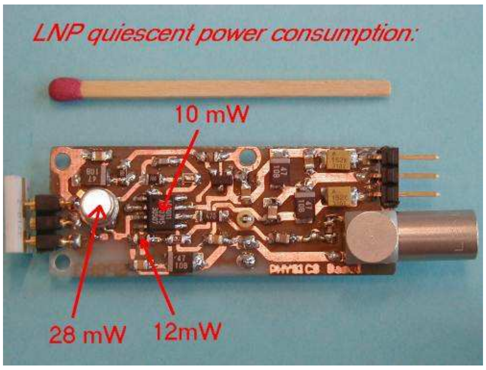
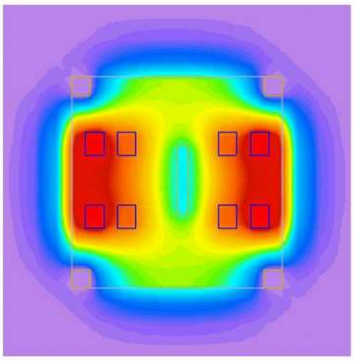


Figure 11: Power dissipation as function of continuous event rate for the LNP preamplifier.





red area: FET's

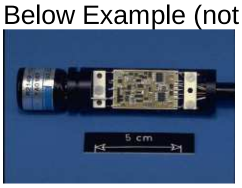
Left: Prototype SP883 Right: simulation quad version SP883b(Proto60)

Magnetic fields
The magnetic field is not changing abruptly. There are no massive connectors and no inductors on the preamp which can cause a high deformation of the field, but several components contents a low amount of magnetic materials (as f.e. nickel) as well as the vacuum photo detectors.
Pretests with no effects on the preamp were executed with 1 Tesla.

Mechanics
The mechanics must provide/work as:

- Holder for the VPT/VPTT in a way that the pins are not getting no forced
- Holder of the preamp and cable
- Metal shielding

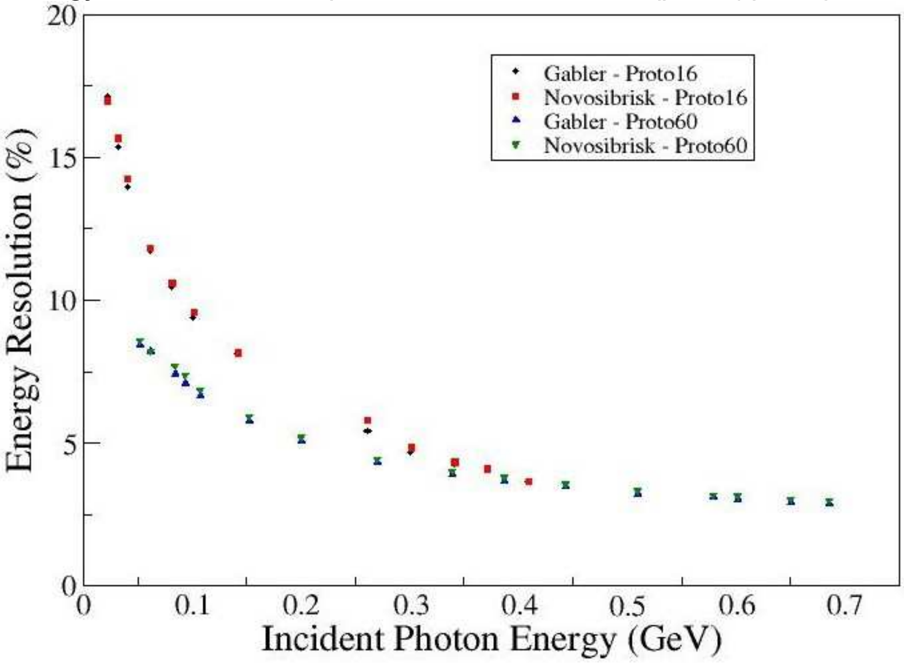
Below Example (not suitable for Panda due to lack of space):



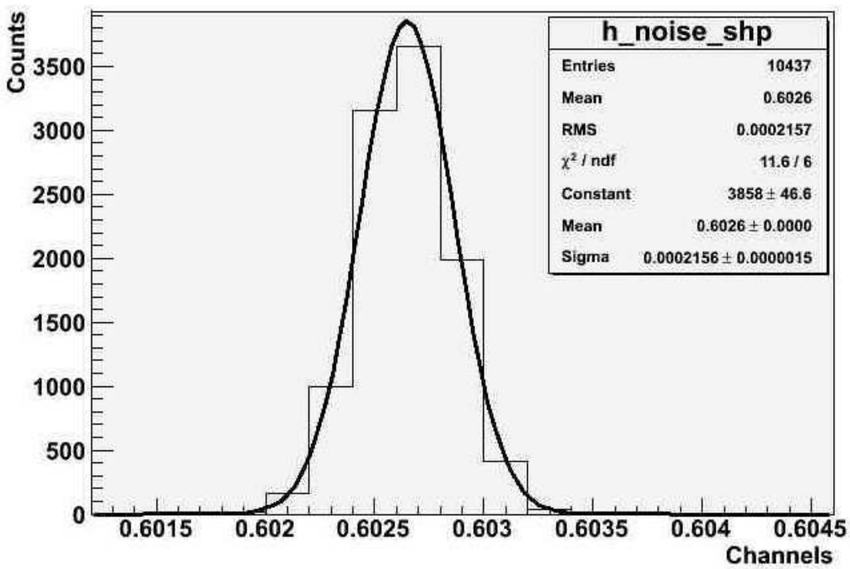
Results

G.Tambave, XXXVth PANDA Collaboration Meeting, 30 Nov. 2010, GSI, Darmstadt

Energy resolution: Comparison of ASIC readout (prototype 16) & LNP readout (Proto60)



→ At lower energies the energy resolution is worst for Proto-16



Noise Level – 4 Stage Shaper with LED light pulser

→ Noise level ~ 1.1 mV, Sigma * 5V ~ 1.1mV

References

Glenn F. Knoll: “Radiation detection and measurement”, 4. Auflage, 2010
E. Kowalski: “Nuclear Electronics”, Springer-Verlag, p.106ff, 163
W.R. Leo: “Techniques for Nuclear and Particle Physics”
Panda: EMC Technical Design Report (Oct. 2008) http://www-panda.gsi.de/framework/det_iframe.php?section=Calorimetry
2008: Technical Design Report GSI Panda ECAL, electronics: chapter 6.3. to 6.7. and 6.9.2
2008: Technical Design Report GSI Panda ECAL, for photodetectors: chapter 5

Myroslav Kavatsyuk et al., Feb. 9, 2011: Performance of the prototype of the electromagnetic calorimeter for Panda, (“Proto60”), accepted Ms. Ref. No.: NIMA-D-11-00181R1, Nuclear Inst. and Methods in Physics Research, A, It will appear on ScienceDirect
2005: Technical Report GSI Panda ECAL p. 203-207
2007: IEEE Transactions on Nuclear Science: Performance of PWO-II Prototype Arrays for the EMC of PANDA

Options

Noise and power consumption is a trade-off. Optimizations are possible in both directions.
Noise and pulse rate/decay time is a trade-off. Optimizations are possible in both directions.
Noise and shaping time is a trade-off. Optimizations are possible in both directions.

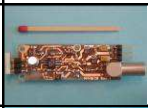
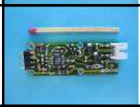
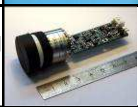
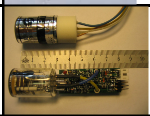
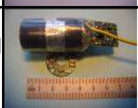
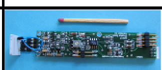
1. To increase the maximum possible burst rate (reduce pile-up) the decay time can be reduced, but then tradeoffs are:
- Higher noise
  and also:
- Higher power consumption
- Higher voltage-drop over HV-filter
- Other shaping time is needed

2. Higher rate (1…1.3MHz)
   A shorter feedback time constant (f.e. 2MOhm<4M4 = ca. 2<5us)
- Better for bursts
- Same for continuous rate
- Higher noise

3. Lower rate dependency: lower bias resistance, leads to more noise
4. Lower dynamic power consumption: Change output impedance 75Ω, 93Ω or 110 Ω (use other cables)
5. Higher output amplitude: no termination resistor doubles amplitude but maybe signal distortion
6. Higher output amplitude: increase power supply voltage to maximum limit (not specified)

SP883a03	*Single APD*	*High Rate (1 MHz)*	*Project R. Novotny, BESSIII*
SP883a0x	Single APD	20mW-Version. (Lower FET current)	Prototype, Sample available

Overview LNP Preamplifier "ChAmp" (Charge Amplifier)-Familiy (Evolution Chart)

Model/Type Photodetector	Photo:	2004/2005	2006/2007	2008/2009	2010	2011	Planned 2012	2013
SP883- Single for APD		Prototypes						
SP883a Single for APD		5x5 array Giessen	15 pcs. tests panda					
SP883b Quad for APD			15x4 Ch. Proto60 array					
SP883a01 Single, short glass VPT				Proto 2008				
SP883a02, single rect. APD improved, 1kV				20xGiessen 1x Beamtest 2x for KVI	60xBW Endc. 3xZwieglinski 2xIgorKonorov 1x A.Wilms	51x Proto192		
SP883a03, single rect. APD, high rate, 1kV							120x Proto192	
SP883c 1kV, short metal VPT (Ham.)				4x Bochum June09				
SP883(c)d VPTT (RIE) 1.5kV				1x Bochum Dez.	3x Bochum			
SP883d_ VPTT (RIE) 1.5kV					10x Bochum	52 Bochum		
SP883d_ VPT (Ham) 1.5kV, (long glass)						66 Bochum 27 Stockholm 2 Giessen	30x Proto192	
SP883d_ VPTT (Ham) 1.5kV, (long glass)						10x Bochum delivered		
SP883d_APD Dual APD, 450V Bias: 3MΩ						50 Bochum	(also for SP883a02 as APD-Adapter without Filter)	
SP883d_HV (HV-Filter round for VPT/T)								
SP883e Smaller, hiRate							Proto 192	
SP917 Single APD				Protos		Protos Crystal Barrel		
SP917c/d, Dual APD/ Paralleled							20 Crystal Barrel	

Low Noise/ Low Power Charge Preamplifier-Family overview + Accessories

ID-Nr.	**Application**	**Description**	**Status/Application**
SP883-	Single APD		Prototyp
SP883a	Single APD		use no longer
SP883a01	Single VPT	Without HV-filter	Tests in Bochum
SP883a02	Single APD	Improved (stability, power supply)	
SP883a02(1kV)	Single APD	New rectangular APD (higher bias voltage)	
SP883a03	Single APD	High rate/Low gain, ? HV-Filter	Proto192
SP883b	Quad APD	48x48mm	
SP883b0x	Quad APD	Preamps + 50 Ohm-Backplane	60 Channels in Proto 60
SP883a01_VPT	Single VPT	+1kV, with HV-Filter for glass housing VPT, 18x48mm	
SP883c	Single VPT	+1kV, with HV-Filter for metal housing VPT, 18x48mm	4 in Test @Bochum
SP883d_VPTT(R)	Single VPTT	For RIE VPTT 1200V, Glass Housing	Proto192
SP883d_VPTT(H)	Single VPTT	For Hamamatsu VPTT 750V, Glass Housing	Proto192
SP883d_VPT(H)	Single VPT/T	For Hamamatsu VPT Glass Housing	Proto192
SP883d_APD	Dual APD	With adapter-PCB for two rectangular APD, 3MΩ-HV-Filter	Proto192
SP883d_HV	VPT/T Ham.	round adapter-PCB for Hamamatsu VPT/T + HV-Filter	Proto192
SP883e	VPT/T, APD	Smaller PCB, higher rate,	Proto192
SP917	Single APD	With shaper, Diff. Driver, temp.-regulated HV	Crystal Barrel
SP917c	Dual APD		Crystal Barrel
SP903a	12 channel	Backplane 50Ω	Proto60
SP903b	Universal	Floating linear LV Power Supply +/- 6V	5 built and in use
SP903c	Teststand	With 2 PMT's for tests	Basel
SP931	DriftChamber	For tests	Basel

Implementations

Prototype	**Panda EMC Type**	**Photodetectors**	**Preamp-type**
Proto 25, 2006	Barrel	1 (APD/Crystal)	SP883a
Proto 60, 2007	Barrel	60 APD (1 APD/Crystal)	SP883b
Proto 50?, 2010	Backward Endcap	APD	SP883a02
Proto 192, 2011	Forward Endcap	ca. 50 VPTT+64 VPT+128 APD	SP883d
Proto xxx, 2012	Barrel	240?APD (2 APD/Crystal)	ASIC

Delivery Model SP883d (without model SP883a02)

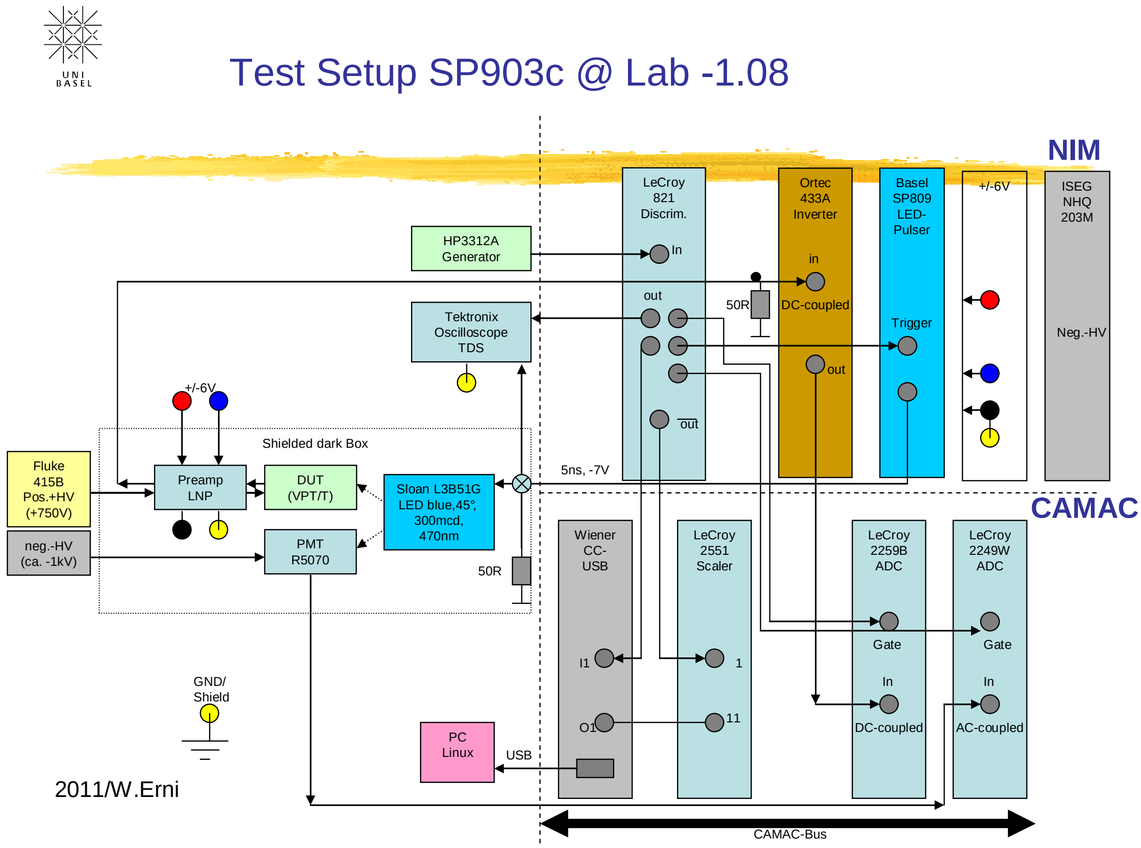
Delivery	Pieces	Version	
December 2010	10	VPTT (RIE)	Bochum (Proto 192)
January 2011	2	VPT (H.)	Uppsala/Stockholm
January 2011	16	VPTT (RIE)	Bochum (Proto 192)
January 2011	2	VPTT (H.)	Bochum (Proto 192)
January 2011	2	VPT (H.)	Bochum (Proto 192)
April 2011	16	VPTT (RIE)	Bochum (Proto 192)
April 2011	16	VPT (H.)	Bochum (Proto 192)
May 2011	34	VPTT (RIE)	Bochum (Proto 192)
May 2011	48	VPT (H.)	Bochum (Proto 192)
May 2011	25	VPT (H.)	Uppsala/Stockholm
May 2011	2	VPT (H.)	Giessen
July/August 2011	96	APD	Bochum (Proto 192)

Contribution Basel group /costs for material for Proto192 (detailed list separate), 2011

Material	**Costs CHF**
266 Stk . Preamps for VPT/T, APD and Adapter-PCB's, etc.	10'000
70 Capsules for APD mounting	5'000
8 Shaper VME modules 16ch. „KVI“	3'000
3 LV Power Supplies	1'000
3 HV-Systems 64 ch. ISEG	180'000
Photodetectors (APD, VPT, VPTT), Hamamatsu	150'000
Total	**349'000**

Test Setup (SP903c)

a.) A light tight, alu-shielded Test-setup with NIM- and CAMAC-Electronics and Linux PC is built.
Operation with LED light-pulses and two PMT's as reference and trigger.



b.) Database for test results, datasheets, etc.: http://jazz.physik.unibas.ch/panda/

c.) The two PCB's dismounted (with 2.54mm SIL-connectors for production testing purpose)

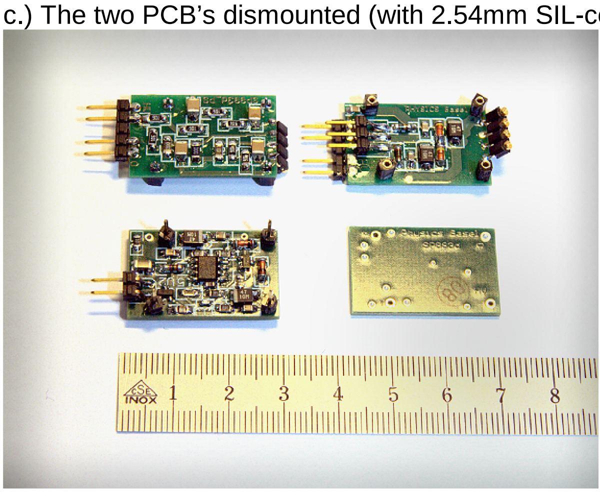


Photo: I.Keshelashvili

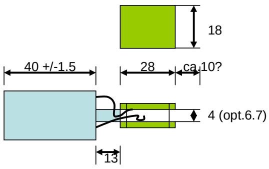
The Prototype SP883(c)d

Built with modified long preamp for pretests for VPTT(RIE) with 1.5kV

VPTT+LNP (c)d Preamp

Prototype in „Sandwich"-Technique for Hamamtsu VPT based on a modified VPT-Preamp SP883c –> SP883(c)d

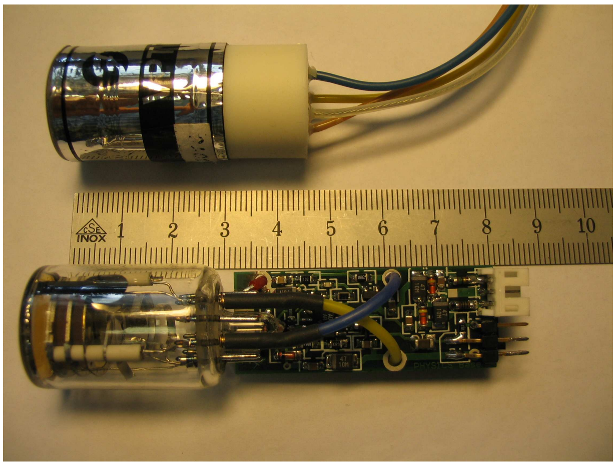
This solution provides:
- Voltage Divider is now integrated on preamp. Rtot 30 MegOhm (=25 uA*750V=19mW) instead of 3x220kOhm (=1.14mA/850mW)
- HV-Caps are 1.5kV
- Total length (without cables) between ca. 70…83 mm (VPT 55mm+Preamp 28mm).
- This should be sufficient, based on a total length with shortest mechanical Interface X5 and Y4 (19mm) of 88mm.
- Contacting without space consuming tube socket or silicone potting
- The wires are soldered direct to the PCB, to fit into the aluminum insert also at the corners
- Short lead connection/lowest capacity from VPT to Preamp provides lowest noise and best immunity.
- A plastic holder provides HV-Isolation.

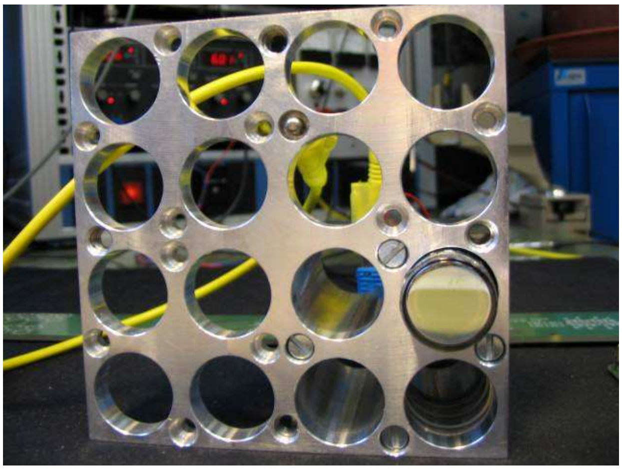


VPT-Body:	40+/-1.5mm
Exhaust cap:	<13mm
PCB:	28 mm
Space for cable:	10mm?

Dimensions in mm, not to scale

2010 11





Glossary/Abbreviations

LNP	Low noise, Low Power Preamplifier
PCB	Printed Circuit Board
VPT	Vacuum Photo Triode
VPTT	Vacuum Photo Tetrode
(LA)APD	(Large Area) Avalanche Photo Diode
PMT	Photomultiplier Tube
RIE	Research Institute Electron, St.Petersburg
Ham./H.	Hamamatsu

Links

Universität Basel, CH	http://jazz.physik.unibas.ch/panda/
GSI Darmstadt, D	http://www-panda.gsi.de/
	http://panda-wiki.gsi.de/cgi-bin/view/SPC/WebHome
	http://forum.gsi.de
Talks	http://www-panda.gsi.de/framework/meetings.php - detectors -EMC-

Thanks to

Fritz-Herbert Heinsius, Thomas Held, et al. Ruhr Universität Bochum, D
Andrea Wilms, GSI; Herbert Löhner, Myroslav Kavatsyuk, Frans Schreuder, et al. KVI Groningen, NL

This work is supported by Schweizerischer Nationalfonds

Figure: GSI, Darmstadt, Germany with FAIR-project

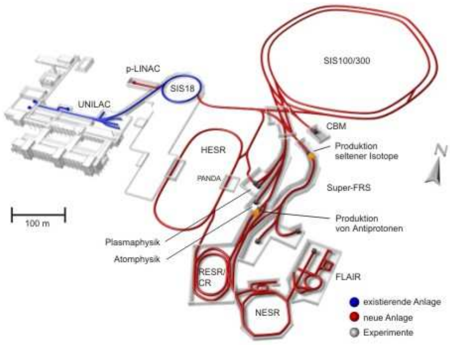


Figure: Artistic view of the PANDA detector and collaboration groups

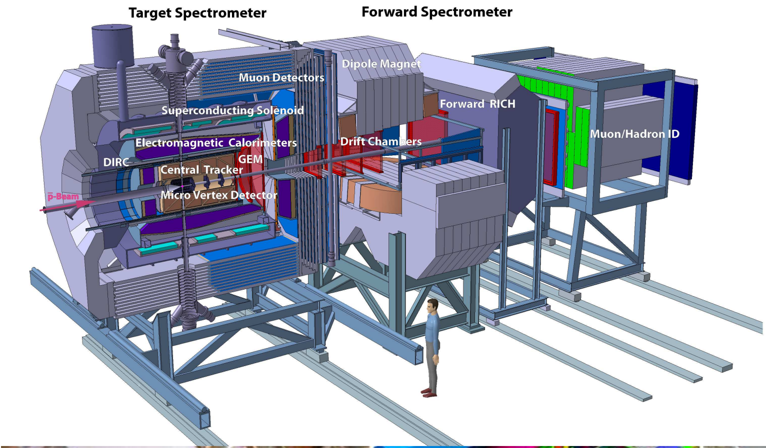
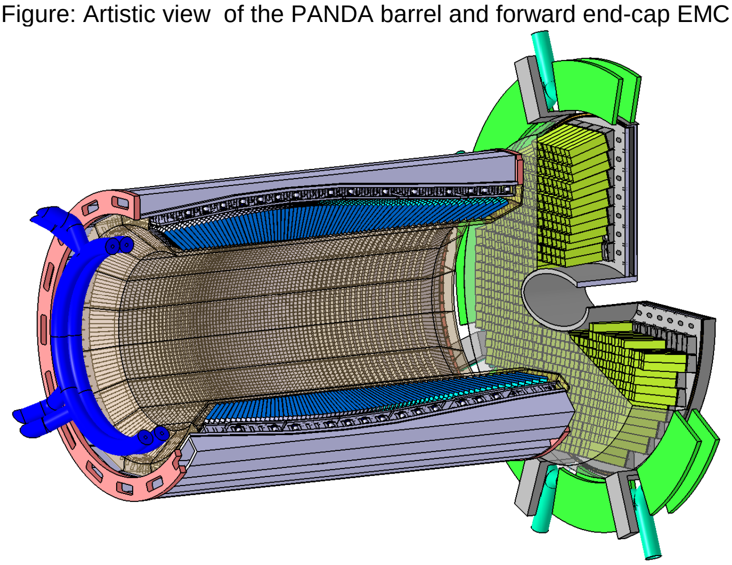


Figure: Artistic view of the PANDA barrel and forward end-cap EMC



Barrel: 11360 PWO tapered Crystals (11 different shapes), 22720 APDs
Forward Endcap: 3856 PWO Crystals, Vacuum Photo Detectors (Triode or Tetrode)/APD’s
Backward Endcap: 592 PWO Crystals, APDs

Contact : Werner.Erni@unibas.ch